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Design optimization of a xerographic auger system

Kip Jugle

DESIGN OPTIMIZATION OF A XEROGRAPHIC AUGER SYSTEM

by

Kip L Jugle

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Title of Thesis -- "Design Optimization of a Xerographic Auger System"

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(Kip L Jugle)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FORWARD

The author would like to acknowledge the following individuals who assisted him during this investigation: Mr. Mark Roszkowski who assisted in running the test, Mr James Lincoln for running the test and keeping the machine running, Dr. Richard Budynas and the thesis committee whose comments on the thesis were helpful and Mr Robert Pictor who supported the author during this endeavor. The author would also like to acknowledge the support of his wife throughout the entire process.

The body of this work was completed in 1996 during the design and test of the next generation developer at Xerox Corporation, Webster New York.

ABSTRACT

This thesis will show how the Taguchi technique can be applied to a complex system and can be optimized with a minimum number of tests. The focus of this thesis is the application of Taguchi methods to the optimization of a xerographic developer auger system. An auger system was optimized to minimize the toner concentration across the magnetic roll. By minimizing the toner concentration variation across the magnetic roll, the visual density variation on the customer prints can be minimized.

The technique was applied by determining the proper control factors that can be used to minimize the variation of the toner concentration. For this study, the auger pitch, auger design, auger speed and mass on the magnetic roll were chosen for the investigation. The worst case print area coverages were used as noise conditions. In this case there were , a blank page, a seventy five percent area coverage and a fifteen percent localized band. The response is the toner concentration standard deviation across the roll.

The technique uses the minimization of the response in the presence of the noise conditions to optimize the system against the noises. The study provides an industrial application of the Taguchi methodologies and resulted in a significant improvement of the xerographic developer housing auger system.

The optimum conditions found to minimize the variation in the toner concentration across the magnetic roll were found to be:

1) The 4890 style Mix auger (a style of auger that is designed to mix the toner and developer more efficiently)

2) The pitch to diameter of the Pick-up auger is optimal at 0.5 (P:D)

3) The speed of the Mix auger is optimal at 200 RPM resulting in a pick-up auger speed of 140 RPM

4) The mass on the magnetic roll is optimal at 0.2 gms/cm^2.

CHAPTER 1.0 INTRODUCTION

1.1 General Statement

This thesis discusses a single step in the overall xerographic process, but a fundamental overview is required for understanding [1]. The Xerographic system is very complex and requires extensive study to fully understand the function and interactions within the process. Xerography was essentially invented by Chester F. Carlson in 1938. The technology has been refined by Xerox Corporation but the fundamental steps remain the same. The Xerographic process consists of five fundamental steps and is shown in a schematic of a xerographic printer in Figure 1. The five steps involved to create a print are as follows:

1) Charging of the photoconductive surface
2) Exposure of the image on the photoconductive surface creating the latent electrostatic image
3) Development of the latent electrostatic image
4) Transfer of the developed image to paper
5) Fixing the image to paper

The photoconductive surface is, as the name implies, insulative in the dark and conductive when exposed to light. This feature allows the photoconductive surface to hold a charge and selectively change the charge on areas of the surface when exposed to light, thereby creating an image. The charging system is used to prepare the photoconductive surface by charging the surface to a known voltage level.

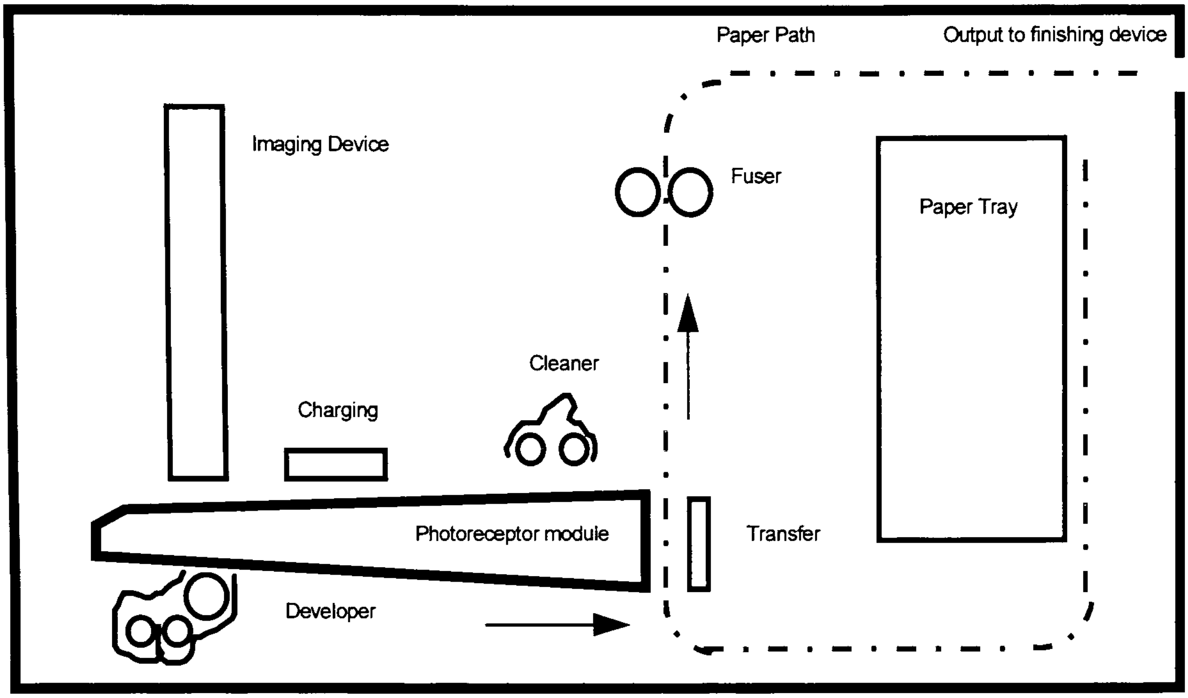


Figure 1
Layout of Typical Xerographic Printer

The charging system consists of one or more devices that have very small diameter "wires" that operate at high voltage levels. The voltage levels on the "wires" are sufficient enough to produce corona which ionizes the surrounding air. The polarity of the ionized air depends on the photoconductive surface being used. The ions are attracted to the surface by maintaining a potential difference between the photoconductive surface and the charging system. This potential difference allows the ions to charge the surface to a known voltage level. The photoconductive surface is shielded from light and this allows the voltage to stay on the surface.

The second step in the process is the exposure of the latent image. Exposure results from allowing light to hit certain areas of the photoconductive surface. The light makes the surface conductive and allows the voltage levels to change only in the areas exposed. The exposure, for the purposes of this paper, is achieved by using a laser system that "writes" (exposes) the image. This exposed image is referred to as a latent electrostatic image. The laser system can either expose the image area or it exposes the non-image area. The rest of the description here will assume a "write black" system where the laser exposes the image. The exposure step results in areas of the photoconductive surface having significantly different voltage levels which enables the toner to be attracted to the image area and repelled by the non-image areas.

The third step is the development process. This is the step in which the latent electrostatic image is brought into contact with the toner. Toner is the "dry ink" that is used to create the image on the paper. The toner is usually presented to the photoconductive surface via the developer subsystem. The developer subsystem can present the toner to the photoconductive surface in a variety of methods. The technology of concern is the magnetic brush developer system. The delivery of the toner is one of several functions performed within the development system. The other functions includes mixing the toner with the developer and imparting a charge to the toner. As the toner is brought into contact with the photoconductive surface the charged toner is attracted to the image areas only. The fully toned image area is then transported to the transfer subsystem.

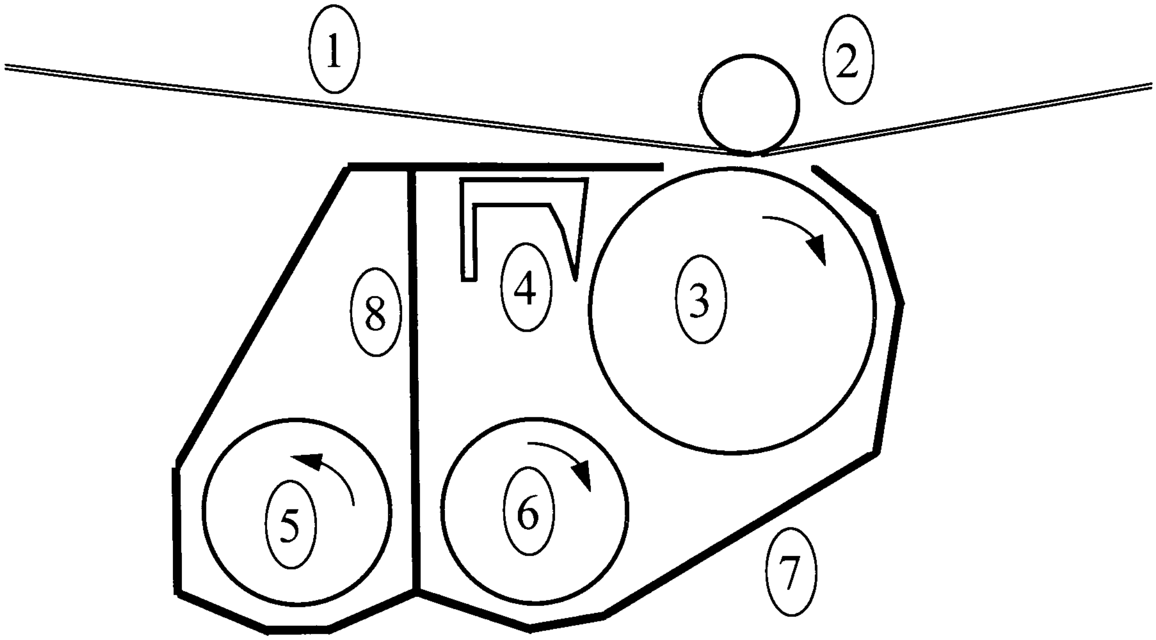
The final steps are required to get the toned image off the photoconductive surface and adhered to the paper. These steps are transfer and fusing. The transfer system uses a electrostatically charged sheet of paper to attract the image from the photoconductive surface to the paper

The final step is simply a heater that is used to adhere the toner to the paper. The heater usually consists of two or more heated rolls that flatten and melt the toner which adheres the toner to the sheet of paper. The subsystem that fixes the toner to the paper is referred to as the fuser. The process is now complete and the print is delivered to the customer.

1.2 Developer Housing Function Description

Prior to describing the developer function a review of terminology and definitions is required. The "dry ink" or toner consists of plastic impregnated with carbon black and a large number of other compounds that are used to control the triboelectrification of the toner. The plastic is ground to a very fine powder. The average diameter of the toner particles is between 7-20 microns depending on the technology and the xerographic process being used. The toner is mixed with ferrite beads that have an average diameter of between 50-150 microns. The diameter depends on the average size of toner being used. This mixture is referred to as developer. The exact chemical nature of the toner and developer is very complex and is proprietary in nature. The amount of toner in the developer is referred to as toner concentration. The toner concentration is the weight percent of toner present in the mixture and is expressed as a percentage. The percent of toner typically is between 3-6%. A toner concentration of 4% in a 5000 gram developer housing means that there is 200 grams of toner and 4800 grams of carrier. The device that measures the toner concentration also measures a another property called tribo. The tribo is a measure of the electrical charge on the toner and is expressed in terms of microcolumbs per gram of toner. The tribo of the toner is required so that the toner can be electrostatically attracted to the latent electrostatic image.

The developer housing consists of four primary components. The location of the these components are shown in Figure 2 , which presents a cross-sectional view of the developer housing.



1) Photoconductor
2) Photoconductor backer bar (maintains flatness)
3) Magnetic Roll
4) Trim Bar
5) Mix Auger
6) Pick-up Auger
7) Extrusion Body
8) Center dividing wall separating the augers

Figure 2

Cross-sectional View of the Developer Housing

The four components that make up the developer housing are the mix auger (item 5), the pick-up auger (item 6), the magnetic roll (item 3) and the trim bar (item 4). The augers are essentially large screws that have an outside diameter of 42 mm and a thread that is about 18 mm deep. An auger of this nature are referred to as pure helical augers. The augers rotate and transport the developer material throughout the developer housing.

The mix auger's primary function is to mix the incoming toner with the resident developer material. The initial design consists of a pure helical auger that is 42 mm in diameter and has a pitch of 18.5 mm. The pitch is the distance between the blades of the auger. The ratio of the pitch to diameter (P:D) is useful in characterizing the augers. The initial design value is 0.44 (P:D) and is a typical value used in many Xerox machines. The secondary function of the mix auger is to transport the mixed developer material to the pick-up auger. The initial speed of the mix auger is 427 revolutions per minute.

The pick-up auger's only function is to transport the developer material to and away from the magnetic roll. The mixing capability of the pick-up auger is kept to a minimum so that the material is picked up uniformly by the magnetic roll. Typically mix augers are quite aggressive and provide very uneven loading of the magnetic roll that results in poor print quality. The initial designs of the mix and pick-up augers are identical helical augers and run at the same speed. The configuration of the two augers was kept the same for the initial developer design to allow hardware to be built and initial testing to take place.

The magnetic roll consists of a 64 mm tube that is rotating at 380 revolutions per minute. The function of the magnetic roll is to transport the developer material to the trimbar and the photoconductive surface. A sketch of the magnetic roll is shown in Figure 3. The magnetic roll has an internal set of magnets that do not rotate with the roll. This magnetic force picks up the material from the pick up auger and holds it against the aluminum tube. The tube has a serrated surface that transports the material around the roll.

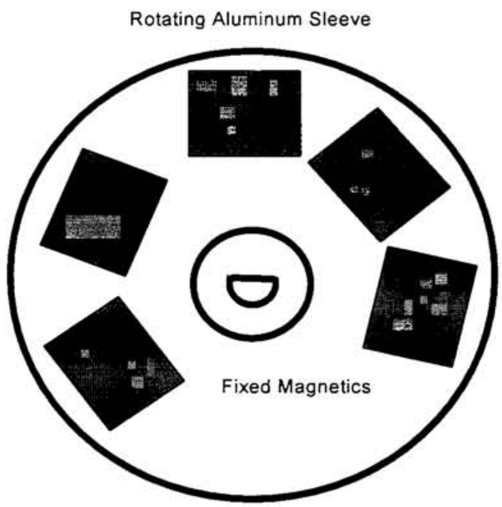
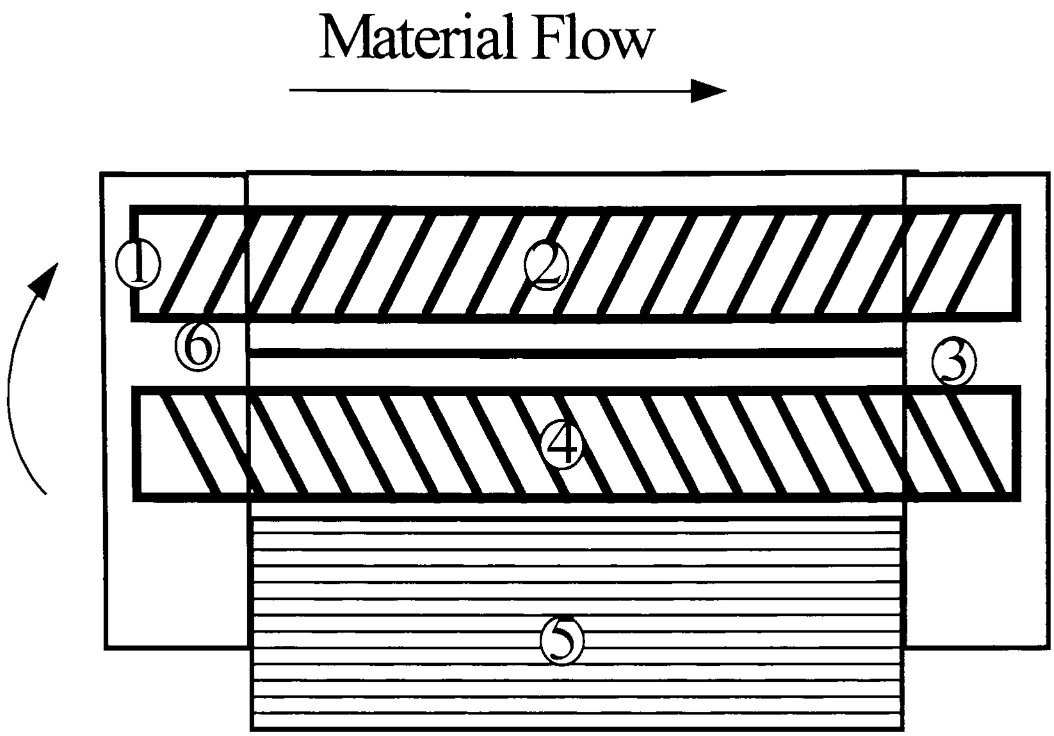


Figure 3
Typical Magnetic Roll with fixed Magnetics and Rotating Sleeve

The last component is the trim bar. The function of the trim bar is to remove excess developer material that is picked up from the pick-up auger. The amount of developer that is left on the tube is approximately 0.22 grams per square centimeter.

This mass on the magnetic roll is referred to as “mass on the roll” and is abbreviated as MOR. This is the amount of developer has been determined to be required to fully develop the latent image in the photoconductive surface.

A top view of the developer housing is shown in Figure 4. The developer flow is indicated by the arrows. Point 1 on Figure 4 is where the new toner is dispensed into the developer housing. The points labeled 3 and 6 are referred to as Hand-off points and are areas that the augers exchange (hand off) material.



1) Dispense Point
2) Mix Auger
3) Hand-off area from Mix auger to Pick-up auger
4) Pick-up auger
5) Magnetic Roll
6) Hand-off area from Pick-up auger to Mix Auger

Figure 4
Top View of the Developer Housing
(trim bar is not shown)

The new toner is dispensed right on top of the mix auger and proceeds down the length of the auger. As the auger rotates the toner is mixed into the developer and is transported towards the pick-up auger. The developer is kept separated from the pickup auger by a center wall. The center wall prevents improperly mixed developer from prematurely getting to the magnetic roll and adversely affecting print quality. At the end of the mix auger the material is transferred, at point 3 in Figure 4, to the pick-up auger. The pick-up auger transports the uniformly mixed developer to the magnetic roll. The magnetic force in the magnetic roll picks up a quantity of developer material and is trimmed by the trim bar. As the roll rotates, the material is presented to the photoconductive surface. While the material is in contact with the photoconductive surface the toner transfers from the developer to the latent electrostatic image. The developer is then transported back to the developer housing and is deposited into the pick-up auger. The material that is returned is mixed with the material resident in the pick-up auger and some material is immediately picked up by the magnetic roll and the process is repeated as the material travels down the auger. This process of repeatedly picking up material that was just used to develop an image results in the possibility of the toner concentration changing locally within the developer housing and resulting in reduced image mass. The reduced image mass results in density variations on the print. The goal of this project is to minimize the local changes in the developer toner concentration. At the end of the pick-up auger the material is handed off to the mix auger where new toner is added to replace the toner that was deposited on to the photoconductive surface.

The amount of toner that is added is controlled via the process controls within the machine. The process controls uses two methods to control the toner concentration in the developer housing. The primary control system is a feed forward system that predicts the amount of toner that was used in making the prints. The area covered by toner on a page is the area coverage and is typically expressed as a percentage of the total available area. The system measures the area coverage and dispenses the appropriate amount of toner. The secondary control system is simply a sensor that is resident in the developer housing that measures the toner concentration directly. The secondary system is just a check on the primary system. The process control system has a minimal effect on the ability of the developer to mix toner into the developer. The process controls can only affect the developer housings ability to mix the toner if the dispense rate is variable and the process controls uses a system in which the rate of toner dispense is modified depending on how far the toner concentration is from target. This type of control currently is not employed on the developer housing being tested. The dispense rate is kept at a constant to maintain the toner concentration. The dispense rate is fixed by the amount of toner that is required on the print.

1.3 Performance Requirements of the Mixing System

The ultimate goal of the developer system is to deliver print quality that is consistent from print one to print ten thousand. The requirement to do this is independent of the content of the print that the customer is making. The criteria that the typical customer uses to evaluate the stability of a print run is very subjective because it is the human observer that is optically determining the stability of the print run. The customer typically evaluates the prints for two optical "defects". The first is background graininess which is the level of toner that is in the background area (non-image area). The background is a result of random deposits of toner particles in the non-image area. The second print quality characteristic is the ability of the toner to cover the paper. As more and more toner mass is added the less the paper shows through. The amount of paper show through can be measured . This measurement is the solid area graininess. The solid area graininess is directly related to the ability of the developer housing to supply toner to the print. If the toner concentration is uneven or too low, the amount of toner on the paper decreases and the solid area graininess will increase. The solid area graininess can be directly correlated to the amount of toner that is placed onto the paper. This mass of toner on the photoreceptor, prior to transferring to the paper, is referred to as developed mass per unit area. Through modeling activities it was determined that a change in toner concentration of greater than 0.45 percent would result in a visible change in print quality. The developer housing performance requirement is to adequately mix the toner into the developer and prevent toner concentration variations on the magnetic roll. The maximum allowable variation in toner concentration is 0.45 percent regardless of the prints that are being run. The definition of toner concentration will be discussed in section 2.2.1. This study of the developer housing will only focus on the variation in the toner concentration on the magnetic roll.

1.4 Statement of the Problem

A review of the literature has shown that within Xerox Corporation, any given developer system requires a certain amount of optimization to effectively mix the incoming toner with the resident developer package. The purpose of this investigation is to optimize the following design parameters.

1) The pitch and geometry of the mix auger

2) The pitch of the pickup auger

3) The relative revolutions per minute of each auger

4) The Mass on the Roll (MOR)

The above design parameters are historically the driving factors in the performance of a developer system. The initial nominal values have been predetermined and are typical of what are used within Xerox Corporation. The focus of the investigation will be to use Taguchi robust design methodology to determine the optimal values with the minimum amount of experiments. This paper will present an actual application of Taguchi methodology as used by industry to facilitate time to market for new products.

Chapter 2.0 TEST METHODOLOGY

2.1 Taguchi Test Description

2.1.1 Introduction [2,3,4]

The Taguchi technique as it is known today was developed by Dr. Genichi Taguchi, after World War II during the reconstruction of Japan. The driving force behind the development was the need to quickly rebuild and advance the manufacturing capability with a minimum expenditure of raw materials and a reduced skilled labor force. The fundamental principles of Dr. Taguchi's techniques is to minimize the variation of a function, thereby improving quality and efficiency. Dr. Taguchi recognized that to quickly improve the country's productivity and quality of goods, a method other than full factorial experimentation needed to be developed. The full factorial experimentation uses two and three level arrays that looks at every possible combination of the experimental factors. Since every possible combination is tested it is extremely time consuming and expensive. It was this need that produced Taguchi's testing methodologies. The mathematics behind the methods employs standard statistical analysis techniques , orthogonal arrays, and analysis of variance (ANOVA) to optimize the function. The analysis of variance technique was founded by Sir Ronald Fisher in England in the 1920s. Fisher's technique defines the variance for each factor relative to the overall mean thereby giving a percentage contribution to the overall mean. The ANOVA technique is widely accepted and used within industry.

The focus of the process is to adequately define the function to be optimized, then minimize the variation of the function due to outside factors that influence the design. The function to be optimized is referred to as the response factor. The response factor(s) is then varied using parameters referred to as a control factors. These factors are defined as those over which the design engineer has explicit control and can be specified on a drawing. Often these factors are confused with noise factors which are outside the control of the design engineer. A typical pair of noise factors might be temperature and humidity.

The design engineer can specify the recommended operating environment but the customer can and often exceeds the design engineer's recommendation.

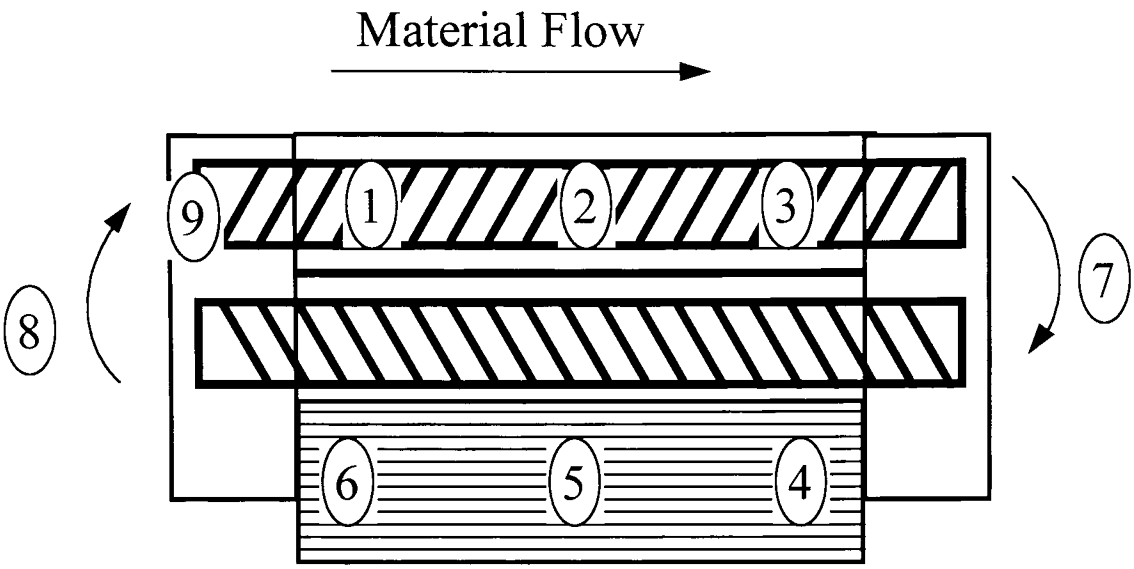
The goal of Taguchi testing and robust design techniques is to maximize the signal to noise ratio of a the system. The maximization of the signal to noise ratio will minimize the variation of the system response that is influenced by outside noise factors and variation of the control factors. The advantages of these methods are quite obvious. If a system is optimized and robust then tolerances on parts can be reduced, thereby producing less expensive parts. By definition a system that is robust will have higher reliability. The reliability is higher since the system has been optimized against the outside noise factors. A system that has better reliability will have fewer system failures. The primary goal of the product engineer is to minimize system failures and satisfy the customers.

2.1.2 Response Factors

Response factors are the factors that are the fundamental output functions of the system being optimized. It is very important to fully understand the system before picking a response factor. The key to successfully using Taguchi optimization is in properly identifying the response factor and the signal to noise ratio to be used. The response factor for the developer housing optimization will be the toner concentration variance at six test points throughout the developer housings. These points are indicated in Figure 5. The toner concentration will be sampled at three points on the magnetic roll (points 4,5,6) and three points on the mix auger (points 1,2,3). These points are chosen for convience and will give an indication of the variation across the housing.

A secondary response will be collected called charge spectography, a distribution of the toner charge. The three charge spectography samples will be taken at the three points along the magnetic roll. The toner concentration measurement technique is described in section 2.2.1. The charge spectography gives an indication of the general toner charge condition and helps in the determination of the ability of the auger system to mix the toner with the developer charge. See section 2.2.2 for a description of the charge spectography measurement.

The variance of the toner concentration across the housing will be minimized during the optimization process. By minimizing the statistical variance in the toner concentration, this will minimize the variation of the toner concentration throughout the developer housing.



1) Test Point 1 (outboard mix auger)
2) Test Point 2 (center mix auger)
3) Test Point 3 (inboard mix auger)
4) Test Point 4 (inboard magentic roll)
5) Test Point 5 (center magnetic roll)
6) Test Point 6 (outboard magnetic roll)
7) Inboard
8) Outboard
9) Toner Dispense Point

Figure 5
Toner Concentration Sample Points

The performance requirements for the housing which are discussed in section 1.3, indicate that a delta of 0.45% toner concentration must be achieved across the magnetic roll. By using all six points, not just the three on the magnetic roll the optimization activity will reduce the overall housing toner concentration variability. The charge spectography data will be analyzed by looking at the mean and standard deviation of the charge spectography plot. The charge spectography will be analyzed at the most stressfull noise condition to maximize the signal within the test. This sample will be taken only at the center of the magnetic roll.

2.1.3 Signal to Noise Ratio [3]

Dr. Taguchi defined four main signal to noise ratios that are most commonly used. The first three are concerned with static type problems. Minimizing the defects in a process is an example of a static problem. The developer auger system will be optimized using static signal to noise ratios. The fourth signal to noise ratio is used in dynamic problems. A dynamic signal to noise ratio is where a signal factor is defined and the optimization process attempts to make the output (response) proportional to the signal factor. The signal factor is simply a factor that has direct influence on the response. The three static signal to noise ratios are the following

a) "larger the better" type
b) "nominal the best" type
c) "smaller the better" type

The "larger the better" type signal to noise ratio is a continuous non-negative function that has the ideal value that is infinite. An example of a "larger the better" type ratio would be the miles driven per gallon of fuel for vehicles or the number of screws produced per hour on a screw machine. These problems are optimized by maximizing the response factor.

There are two types of ""nominal the best"" signal noise ratios. Type I functions are characterized as having an ideal value that is non-zero and finite. The type II functions are those that can have both negative and positive values and the ideal value is zero. An example of a type I problems is output from a DC power supply for a CD player or the temperature of the air from a hair dryer. The type I signal to noise ratio will be used for evaluation of the charge spectography data. An example of a type II problem could be the skew of an image on the paper from a printer or copier.

The last signal to noise ratio is referred to as ""smaller the better"". The "smaller the better" ratio is characterized as continuous and non-negative and the ideal value is zero. The goal of the optimization is to minimize the variation of the response. The signal to noise ratio for the toner concentration analysis is a "smaller the better" case since this will minimize the variation in the toner concentration across the developer housing. The signal to noise ratio used to minimize the variance is [3] :

$$\text{signal to noise ratio} = -10 \operatorname{Log}_{10} (\sigma^2) \qquad (1.0)$$

where σ^2= variance of the six sample points

Using equation 1.0 will allow the maximization of the signal to noise ratio to minimize the standard deviation of the toner concentrations throughout the housing. Simple inspection of equation 1 shows that the larger the standard deviation for any given set of data will result in a smaller signal to noise ratio. The opposite is also true, the smaller the standard deviation the larger the signal to noise ratio. In using all six points in the analysis the variation around the housing will be minimized and provide better function.

To ensure that the toner is mixed properly, the charge spectography data is also analyzed. This secondary response is used to check for inconsistencies in the primary response and checks the ability of the system to charge the toner. The ideal charge spectography distribution is gaussen in nature, tight, and is not centered at zero charge. A distribution of this nature would be an indication of a uniform charge on the toner particles at the same polarity and charge level. The charge spectography data has several key characteristics that are important and are good indicators of the general shape of the distribution. One of these characteristics was analyzed and is called Q/D (charge/diameter). The Q/D has the units of coulombs/micron. The signal to noise ratio for the charge spectograph is neither the "smaller the better" nor the "larger the better" but is a case of nominal is best [3]:

$$\text{Signal to noise ratio} = 10 \log_{10} (\mu^2/\sigma^2) \qquad (2.0)$$

where μ= average Q/D

σ= standard deviation

A decrease in the average Q/D, an increase in the standard deviation in the Q/D, or a combination of the two would result in the lowering of the signal to noise ratio. The maximization of the signal to noise ratio will result in a tight and narrow distribution for the charge spectography. This type of distribution is indicative of uniformly mixed toner and developer and should lead to a minimum of toner concentration variation in the housing. The charge spectography data will be analyzed at the end of the 75 % area coverage noise instead of across all of the noise factors. The reasons for using a single point will be discussed in section 3.2. There are no functional relationships between equations 1 and 2. The two equations are formulas for distinct signal to noise ratios.

2.1.4 Control Factors

The control factors are factors that the design engineer can control which drive the performance, or lack of performance, of the system. The control factors that influence the developer housing system include, but are not limited to, the following:

Auger diameter
Auger pitch
Auger speed
Auger vane thickness
Auger length
Auger style
Toner material properties
Magnetic roll speed
Mass on the roll (MOR:amount of developer material on the magnetic roll)

This list is not totally inclusive, but many of the control factors are out of the author's control. The toner material properties are a case in point. These properties are extremely complicated and are dictated by other functions. The toner material properties are dictated by half a dozen print quality attributes that include line quality, the ability of the system to produce halftone patterns and the ability to develop solid area. It is the auger systems function to properly mix the toner and developer. Some of the control factors are fixed due to other problems and will not be considered in this investigation. For example, the diameter is fixed to provide the proper housing mass and auger to wall clearance. The vane thickness is chosen to provide the required strength of the plastic molded part.

The four control factors that are tested in this optimization study are:

Mix Auger Configuration
Pick-up Auger Configuration
Mix Auger Speed
Mass on the roll

The levels for the control factors are chosen based on previous test work and experience. The mix auger configuration would have two levels that are designated as "HELICAL" and "4890 style". The Helical augers can be seen in Figures 6, 7 and 8, which show the three pitch to diameter ratios used in the optimization. Figure 9 shows the 4890 style auger. The 4890 style auger is a pseudo auger that has flat features that assist in the mixing and reduce the transport efficiency of the auger. The pick-up auger would have three levels of pitch to diameter ratios that would range around the nominal design. The levels chosen are 0.3, 0.5 and 0.7. A level less then 0.3 would result in very tight spacing on the auger vanes and significant reduction in the housing mass. At levels greater than 0.8 will eventually lead to an auger that is not functional. The functionality is lost due to an angle change on the face of the augers as the P:D ratio increases. At the high ratios there is a larger force imparted on to the developer material that is perpendicular to the centerline of auger instead of parallel thereby reducing its ability to transport material. The requirement for the pick-up auger to be helical and less aggressive than the mix auger is because the overly aggressive mixing type auger in this position results in uneven loading of the magnetic roll which results in non-uniform print quality. The speeds of the mix auger are also chosen again to vary around the nominal design intent. The speed of the pick-up auger is an outcome after the level of the material is balanced. The speed of the pick-up auger is varied until it is transporting the same amount of developer as the mix auger. The speed of the pick-up needs to be varied so that the developer material is constantly flowing. If a balance between the pick-up auger and the mix auger is not maintained it is possible to block one of the auger paths at the hand-off points thereby causing the augers to stop and the housing to fail. The mass on the roll (MOR) is varied about the nominal and ranges from 0.2 gm/cm^2 to 0.3 gm/cm^2 .

The control factors are as follows:

Control Factor	**Level 1**	**Level 2**	**Level 3**
Mix Auger Configuration	4890 style	Helical	4890 Style
Pickup Auger Type	0.3 P/D	0.5 P/D	0.7 P/D
Mix Auger Speed	400 RPM	300 RPM	200 RPM
Mass on the Roll (MOR)	0.2 gm/cm^2	0.25 gm/cm^2	0.3 gm/cm^2

The above control factors and levels have been selected so that the performance of the system can be improved. The optimization process will now determine the specific levels at which the control factors need to be set to yield the performance that is required of the system. The levels of the control factors were chosen based on typical levels found within other developer auger systems in use at Xerox Corporation.

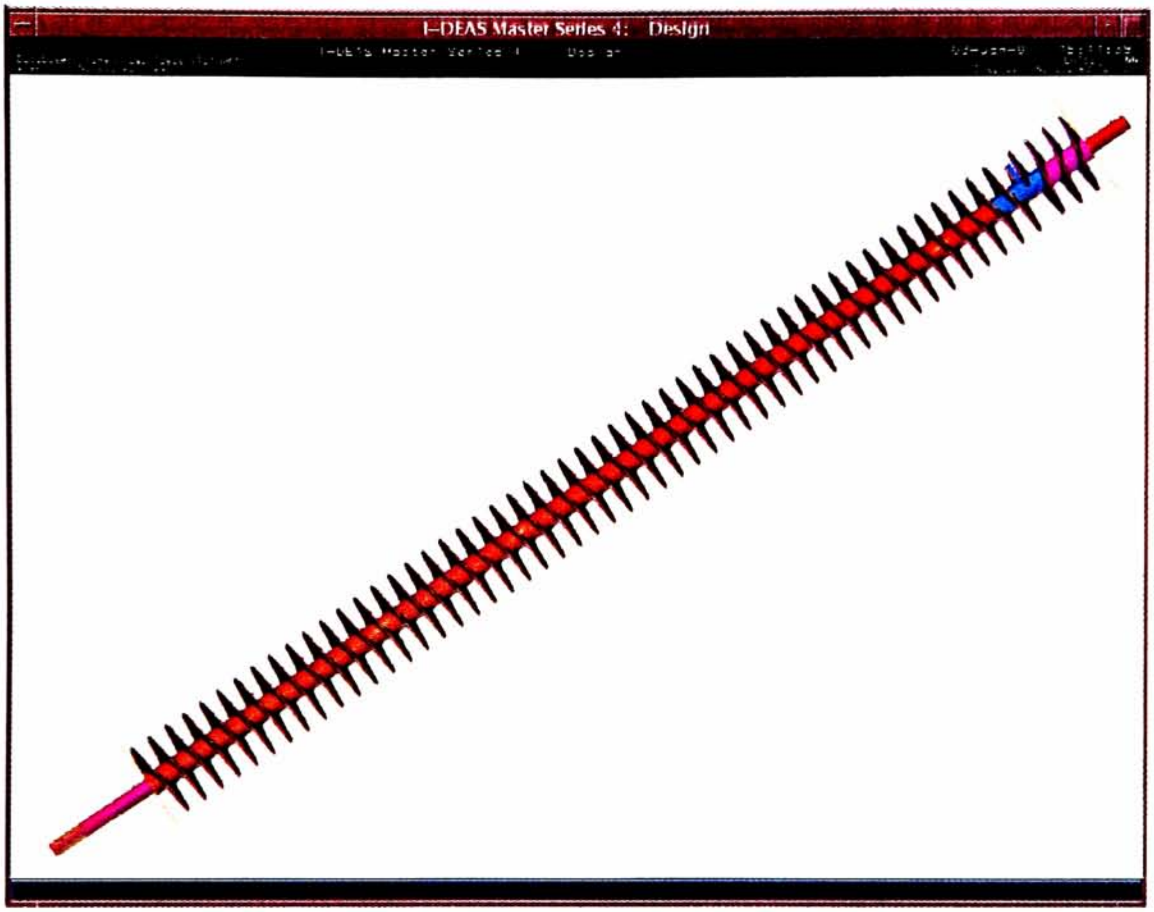


Figure 6
Helical Auger with 0.3 Pitch Diameter Ratio

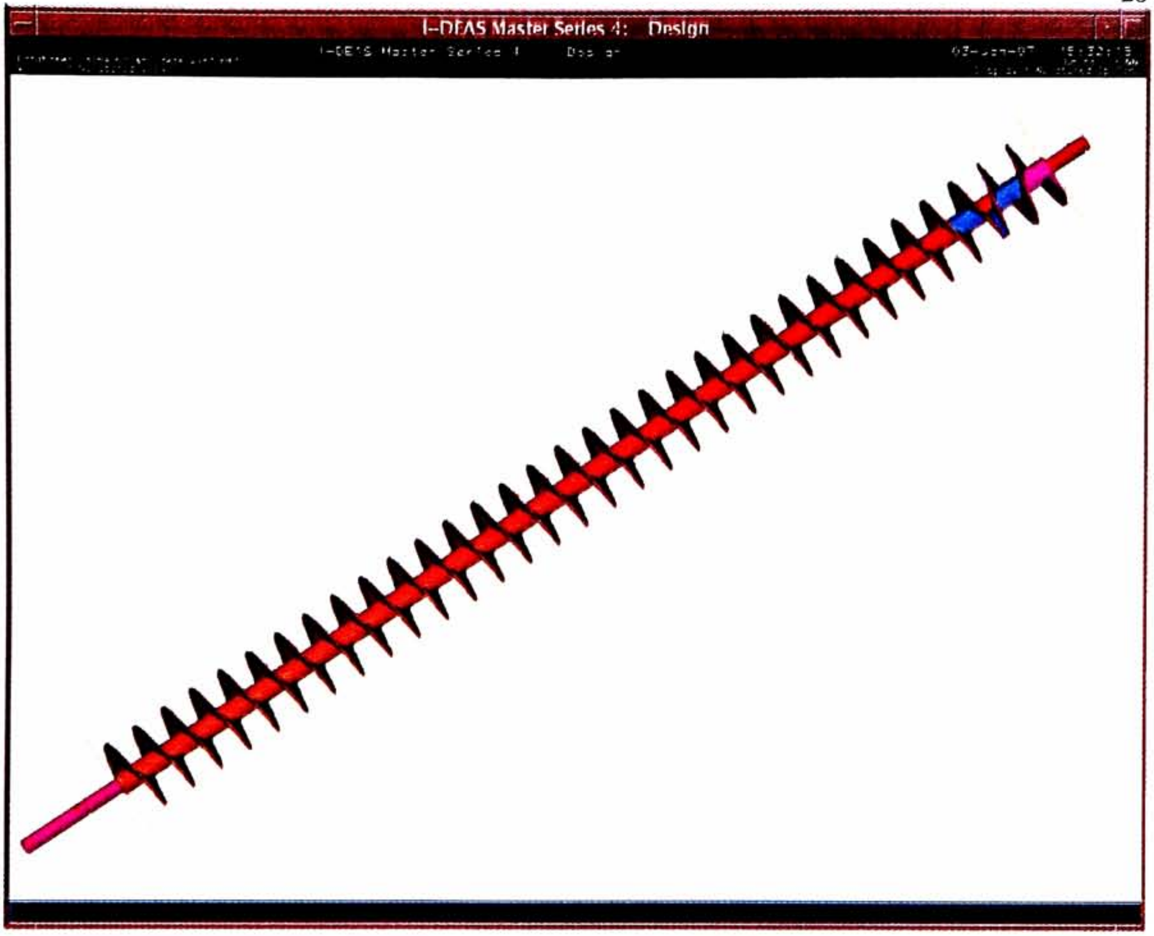


Figure 7
Helical Auger with a 0.5 Pitch/Diameter Ratio

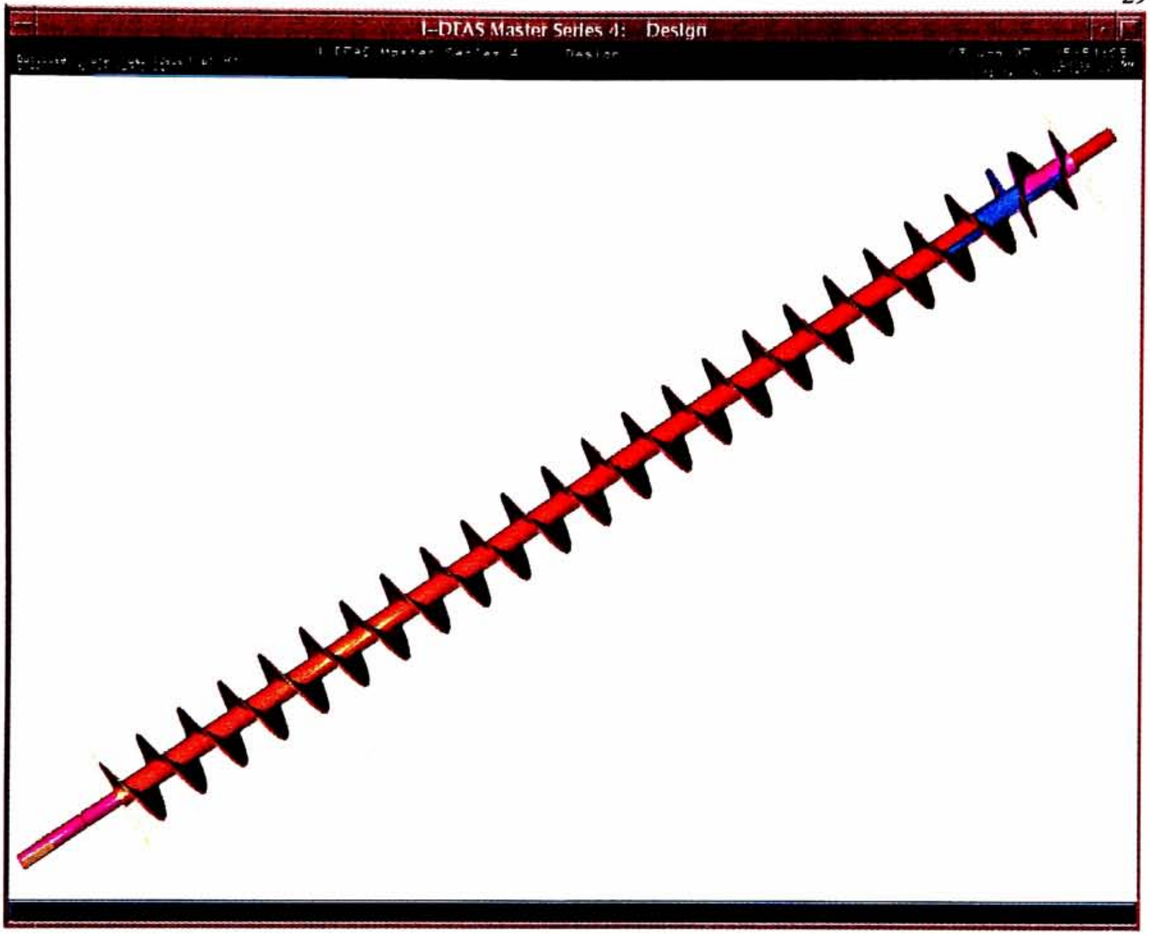


Figure 8
Helical Auger with 0.7 Pitch/Diameter Ratio

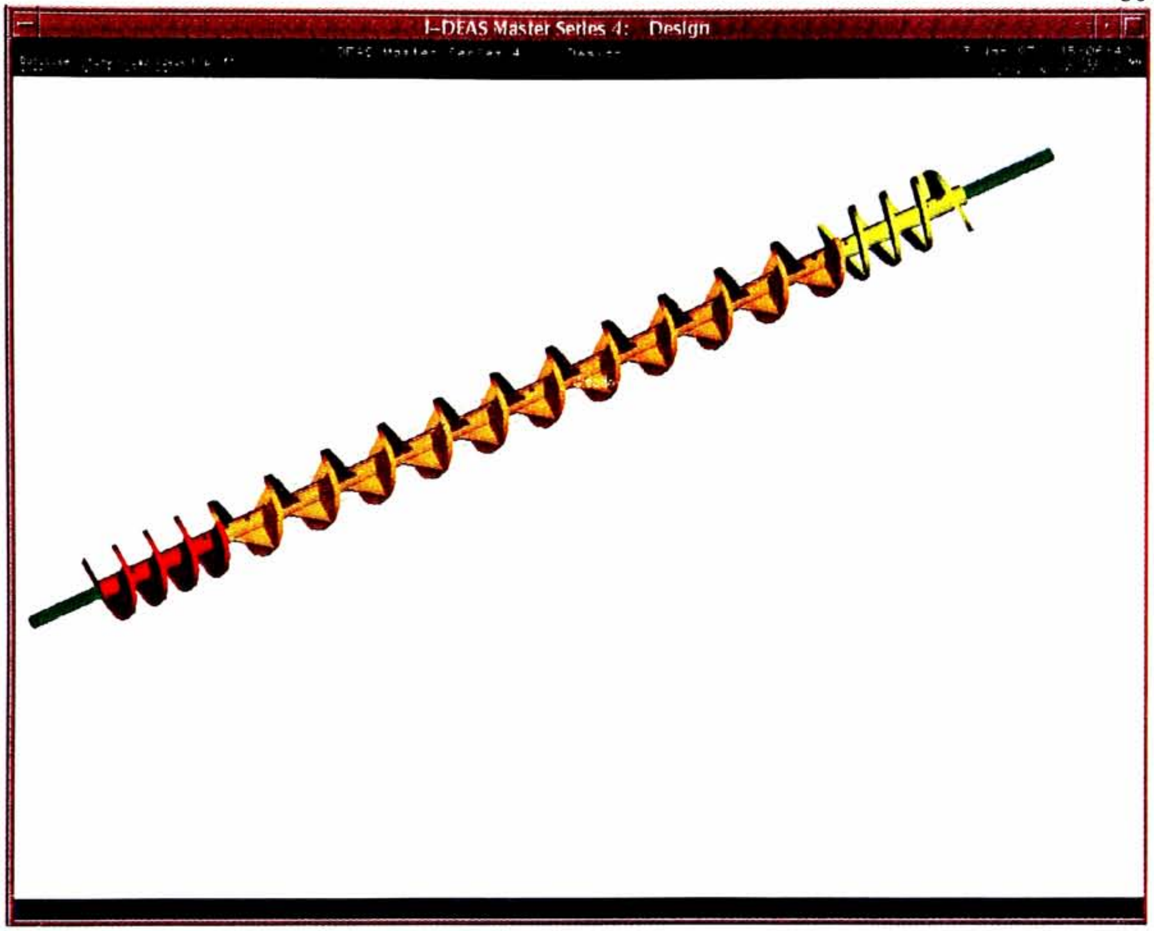


Figure 9
4890 Style Mix Auger

2.1.5 Noise Factors

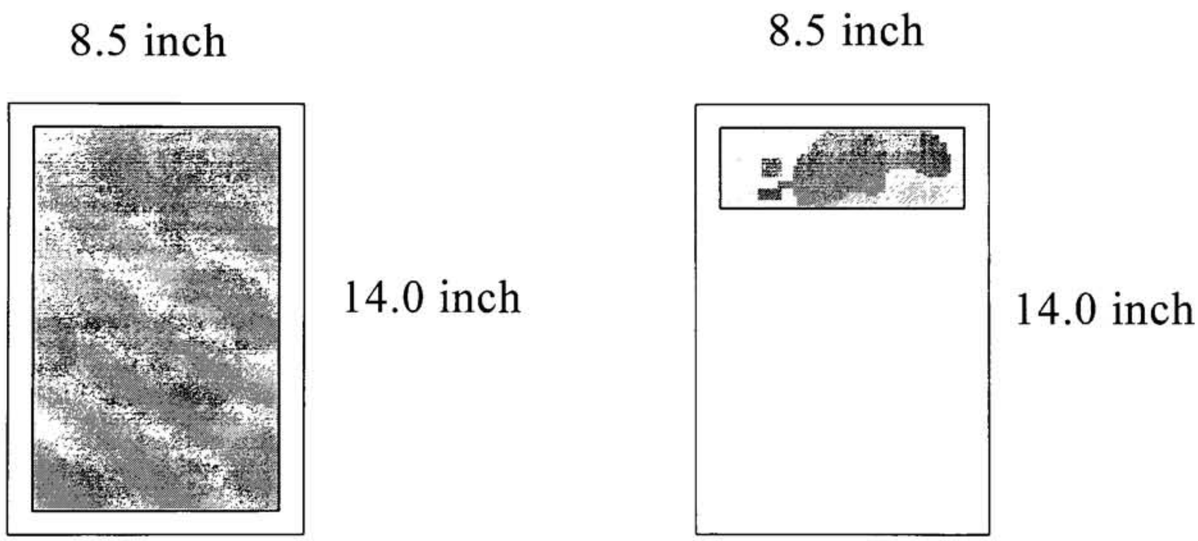
A noise factor is a parameter that is uncontrolled and has the potential to affect the performance of the developer housing. The list of potential noise factors is very long. Some of these noise factors include but are not limited to the following:

Temperature/Humidity
Average Toner Concentration
Housing mass
Toner Material properties (diameter, additive level,etc)
Auger material properties
Auger to wall clearance
Area Coverage (amount of toner on page)

For the purpose of this test the relevant noise factor is the area coverage that the customer can run. The area coverage is the noise condition that will cause the greatest variability in the toner concentration. The inability to predict the area coverage and the customer's ability to randomly design the prints makes the area coverage an ideal noise. The developer system needs to be robust against any print document layout that the customer may run. Three area coverages are chosen that historically show a stress for the development system. The area coverages are:

Noise Factor	Level 1	Level 2	Level 3
Area Coverage	0%	75%	15% band

The 75% and the 15% band documents are shown in Figure 10. The 0 % area coverage document is a control that will give the best performance in terms of charge distribution and toner concentration deviation across the housing. The print is a blank page that will not cause any toner to be removed or added to the housing.



75 % area coverage document 15% area coverage band document

Figure 10
Document Layout
(0% area coverage not shown)

The 75 % area coverage is an extremely high area coverage that removes a large amount of toner from the housing. This requires the housing to mix a large amount of incoming toner. The document is solid area coverage except for a 0.5 inch white band (no toner) that surrounds the document. The 75% area coverage document will stress the system in terms of being able to adequately mix and charge the toner adequately.

The last level is a 15 % area coverage that is concentrated on one end of the document. This is one of the stresses for a variation across the roll. The band document is simulating a localized high area coverage which is usually more difficult to mix properly. This area coverage will be the stress for adequately mixing the toner concentration across the length of the magnetic roll.

The three noises chosen should cover the gamut of area coverages that a customer will run. If the housing is optimized so that it is robust against these three stress area coverages it will be robust to any potential prints that the customer may run. The test procedure is written so that enough prints are run to avoid transients in the toner concentration variation. Based on past programs and previous work with the toner and developer material, 500 prints should be adequate to reach a stable condition. The complete test procedure will be discussed in section 2.2.3.

2.1.6 Test Design

Dr. Taguchi identified a series of eighteen basic orthogonal arrays. The orthogonality of an array is defined as "giving the array balance and the capability of producing data that allow for the independent quantification of independent factor effects"[4] The arrays are named for the number of rows that the array contains. The number of rows in the array are the number of experiments. The terms "experiment" and "cell" will be used interchangeably throughout this study. The number of rows required in the array is equal to the degrees of freedom required for the optimization.

The previous sections have shown that there are four control factors that have three levels each. In addition there are three noise levels that need to be tested. Using a full factorial design it would require 243 experiments to complete the testing (3^4X 3 noise levels). The degrees of freedom for this particular optimization is nine, one for the overall mean and eight for the four control factors. As discussed above the nine degrees of freedom dictates that at least nine experiments be run. Since there are four control factors at three levels each, an L9 is the smallest experiment that could be run. The next orthogonal array that could be used would be an L18 which allows for one two level control factor and seven three level control factors. However, this will give sixteen degrees of freedom when the optimization only requires nine. The additional degrees of freedom would be wasted and is an inefficient use of testing resources. The L18 may have given slightly more precision in determining the factor effects. The L9 will allow the optimization to be completed in nine experiments plus two verification experiments. The L9 experimental design layout is found in Table 1[3] :

Table 1

L9 (3^4)Orthogonal Array

Experiment	Control Factor A	Control Factor B	Control Factor C	Control Factor D
1)	Level 1	Level 1	Level 1	Level 1
2)	Level 1	Level 2	Level 2	Level 2
3)	Level 1	Level 3	Level 3	Level 3
4)	Level 2	Level 1	Level 2	Level 3
5)	Level 2	Level 2	Level 3	Level 1
6)	Level 2	Level 3	Level 1	Level 2
7)	Level 3	Level 1	Level 3	Level 2
8)	Level 3	Level 2	Level 1	Level 3
9)	Level 3	Level 3	Level 2	Level 1

Due to the time, cost constraints and inefficiency an L9 was chosen over an L18. The L18 would have allowed the testing of up to seven control factors at one time but would have doubled the length of the test. The L9 that was used can be found in Table 2. The result of using an L9 will be that if the control factors in the first two columns (auger style and auger pitch/diameter ratio) have interactions, these interactions will be confounded with the last two columns. The confounding means that if there were significant interactions between the columns there wouldn't be a way to distinguish the affects of the columns independently. If there are interactions, the confounding will result in an optimization that will have a larger than expected error and the optimization will not verify. However as long as the complete optimization is verified there is little concern that the optimization is incorrect. The hardware design does not permit the elimination of these interactions, therefore the system optimization needs to be robust against any possible interactions that negatively affect the system. The objective of this work is to optimize the system; it is not required that full comprehensive understanding of the system be obtained. This allows the optimization to be completed in a timely fashion.

The experimental design layout with the relevant control factors and the appropriate levels is shown in the control factor matrix in Table 2:

Table 2

Experimental Design Layout (L9)

Experiment	Mix auger configuration	Pick-up Auger Configuration	Mix auger Speed	MOR
1)	4890 style	0.3 Pitch/Dia	400 rpm	0.20 gm/cm^2
2)	4890 style	0.5 Pitch/Dia	300 rpm	0.25 gm/cm^2
3)	4890 style	0.7 Pitch/Dia	200 rpm	0.30 gm/cm^2
4)	Helical	0.3 Pitch/Dia	300 rpm	0.30 gm/cm^2
5)	Helical	0.5 Pitch/Dia	200 rpm	0.20 gm/cm^2
6)	Helical	0.7 Pitch/Dia	400 rpm	0.25 gm/cm^2
7)	4890 style	0.3 Pitch/Dia	200 rpm	0.25 gm/cm^2
8)	4890 style	0.5 Pitch/Dia	400 rpm	0.30 gm/cm^2
9)	4890 style	0.7 Pitch/Dia	300 rpm	0.20 gm/cm^2

The order of the experiments to be run is not critical for the analysis. Since each row is a complete test and is run identically there is not a need to run the L9 in order. The order will be determined by minimizing the time between experiments . In this study the first two control factors are the most difficult to change. Therefore, once an auger configuration is set-up then all possible cells will be run before the auger configuration is changed. For example, if row one is run first the next cell to be run will be row seven.

2.2 Test Method

2.2.1 Toner Concentration Measurement

The toner concentration measurement is a very simple measurement to make but is relatively time consuming. The device that measures the toner concentration consists of a steel Faraday cage that allows a sample to be placed in it. The ends of the cage have a 30 micron screen that allows the 7 micron toner to pass but prevents the developer from leaving the cage. An air stream is used to blow the toner off the developer and allows the user to weigh the developer with and without the toner. The toner concentration is calculated by dividing the weight of the toner by the weight of the carrier (developer without toner). The ratio of the toner weight to carrier weight is multiplied by one hundred to give a percentage.

In addition, the steel cage is attached to a electrometer that allows the charge on the cage to be monitored. As the toner is stripped from the developer, the charge on the cage changes. This charge on the material is called Tribo. The name comes from the method, triboelectrification, that is used to charge the toner within the developer housing. It is measured in microcoulombs per milligram. The Tribo of the material is the average bulk charge of the toner in the sample. For detailed charge information, the charge spectography is used.

2.2.2 Charge Spectography Measurement

The charge spectography measurement is used as a secondary response because it gives a good indication of the ability of the auger system to mix the toner. An auger system that gives a poor charge spectography distribution will result in a large toner concentration variation throughout the developer housing. The charge spectography measurement gathers a large amount of data on the condition of the toner on a microscopic scale. The data is a measure of the specific charge on the toner, the number of toner particles in the sample, and the average diameter. One of the important pieces of data that is commonly used is the charge to diameter ratio (Q/D). This ratio gives the tribo charge of the toner tested with respect to the diameter of the toner. The Figures 11a and 11b show two resulting graph from the charge spectography analysis

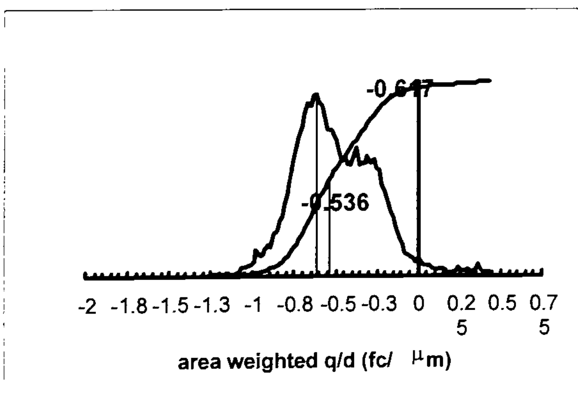


Figure 11a

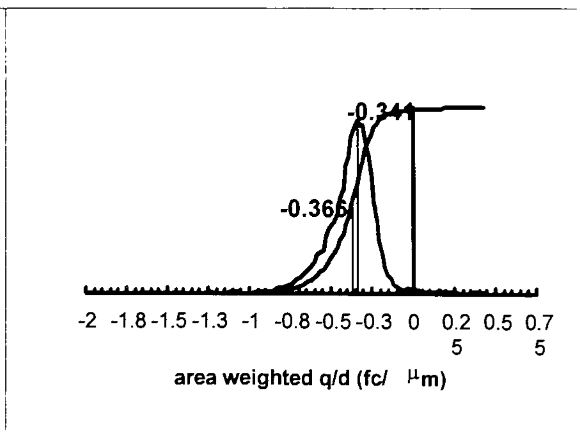


Figure 11b

Typical Charge Spectography Graph

There are actually two plots shown on each graph. The single line is a cumulative distribution of the toner particles. There are two numbers on the graphs. One is the mean of the distribution and the other is the 50% point on the cumulative distribution. The cumulative distribution is an outcome of the charge spectography analysis and is not used in this study. The x axis is the area weighted Q/D (femto-coulombs/ micron). The y axis is the average charge. Figure 11a shows a wide distribution with a bipolar average, while Figure 11b shows a tight and narrow distribution.

2.2.3 Test Procedures

The housing configuration is set-up prior to the start of each cell (each experiment). It is not required to run the experiments in order nor to randomize the nine experiments. The order of the experiments was determined by minimizing the time between the cells. The housing toner concentration is set at 5 +/- 0.25% and greater than 20 microcoulombs per milligram. The toner concentration level was chosen as a stress for the performance requirements of the housing. The level of each control factor is set and verified prior to the start of the cell. The test was designed to run 1500 prints at the 75% and the 15% area coverage points to allow the system to reach a stabilized state. The following steps were the procedures used to complete each cell:

1) Print 200 0% area coverage documents
   - take toner concentration samples at points 1,2,3,4,5,6
   - take charge spectography samples at positions 4,5,6
2) Print 100 75% area coverage documents
   - take toner concentration samples at points 4,5,6
   - take charge spectography samples at positions 3,4,5
3) Print 100 75% area coverage documents
   - take toner concentration samples at points 4,5,6
4) Repeat step 3 for three additional print runs
5) Print 500 75% area coverage documents
   - take toner concentration samples at points 1,2,3,4,5,6
6) Print 500 75% area coverage documents
   - take toner concentration samples at points 1,2,3,4,5,6
   - take charge spectography samples at positions 3,4,5
7) Check toner concentration point 5 and adjust to 5 %
8) Print 100 15% area coverage documents
   - take toner concentration samples at points 4,5,6
   - take charge spectography samples at positions 3,4,5
9) Print 100 15% area coverage documents
   - take toner concentration samples at points 4,5,6
10) Repeat step 3 for three additional print runs
11) Print 500 15% area coverage documents
   - take toner concentration samples at points 1,2,3,4,5,6
12) Print 500 15% area coverage documents

-take toner concentration samples at points 1,2,3,4,5,6
-take charge spectography samples at positions 3,4,5

13) Print 200 0% area coverage documents
-take toner concentration samples at points 1,2,3,4,5,6
-take charge spectography samples at positions 4,5,6

Step 7 was added after the initial testing indicated the toner dispensing system could not control the toner concentration and maintain 5%. Any cells that had a drop in toner concentration at the inboard end greater than 0.5% would be retested. The retests happened twice and the only section that was retested was the 75% area coverage run. In addition to the toner concentration and charge spectography samples five 0% coverages documents and five analytical targets were saved.

The data collection for each experiment is very time consuming and expensive. The toner concentration samples take approximately 3 hours to run at a cost of $45 per hour. The 18 charge spectography samples are run and cost about $60 per sample. The total cost of each cell for data collection alone is approximately $1200 per cell. This does not include the labor cost for running the cell.

CHAPTER 3.0 RESULTS

3.1 Toner Concentration Analysis

The raw toner concentration data for the entire experiment can be found in Appendix A. There are eleven cells of data in the appendix, nine from the orthogonal array and two additional. The two additional cells of data are the optimized system and the system prior to optimization. The toner concentration data was plotted versus the print count for each of the six sample points and the three noise conditions. The mapping of the print count and the corresponding noise conditions can be found in Table 3.

Table 3
Noise condition and Print Count

Noise Condition	Area Coverage	Print Count
Noise 1	0% Area Coverage	200
Noise 2	75% Area Coverage	1200
Noise 2 replicate	75% Area Coverage	1700
Noise 3	15% Area Coverage	2700
Noise 3 Replicate	15% Area Coverage	3200
Noise 1 Replicate	0% Area Coverage	3400

Figure 12 shows the toner concentration plot for the first cell of the test. The data at each print count represents the six sample points that were shown in Figure 5.

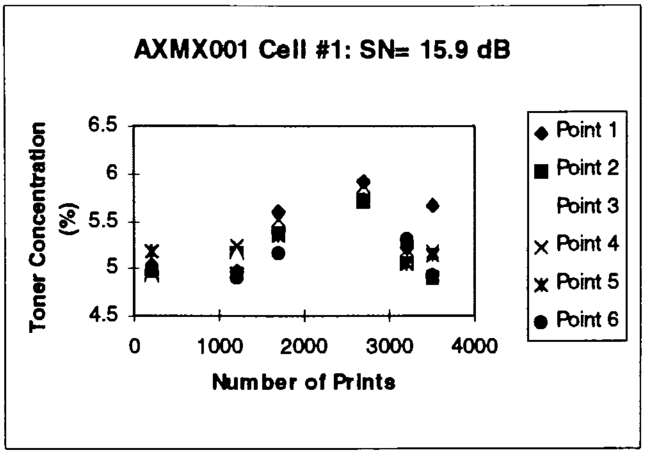


Figure 12
Cell 1 Toner Concentration Plot

By observing Figure 12 it is quite evident that there is a significant toner concentration variation throughout the 3400 print test. For this particular cell, the toner concentration varied from about 6% to just under 5%. The objective is to have a system that could maintain a nominal toner concentration and not vary by more than +/- 0.45%. The ideal auger system would have the six sample points tightly distributed at each noise condition and have each noise condition average tightly distributed about a specified average. In the title for each plot the "SN=" is indicating the value of the signal to noise ratio that was calculated for the particular cell. These calculations will be reviewed in this section. The rest of the cells, cell 2 through cell 9, can be found in Figures 13 through Figure 20.

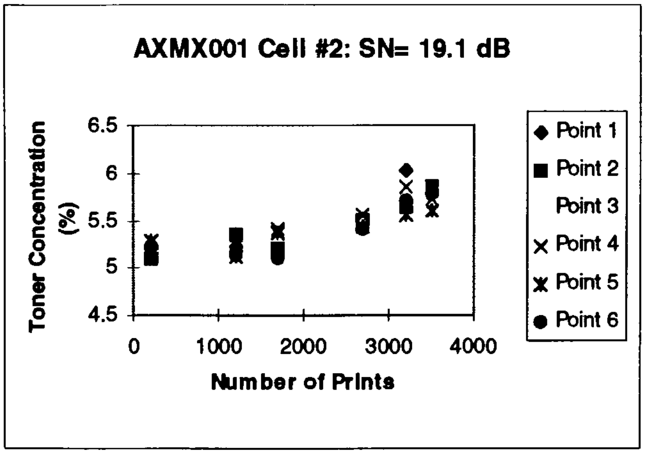


Figure 13
Cell 2 Toner Concentration Plot

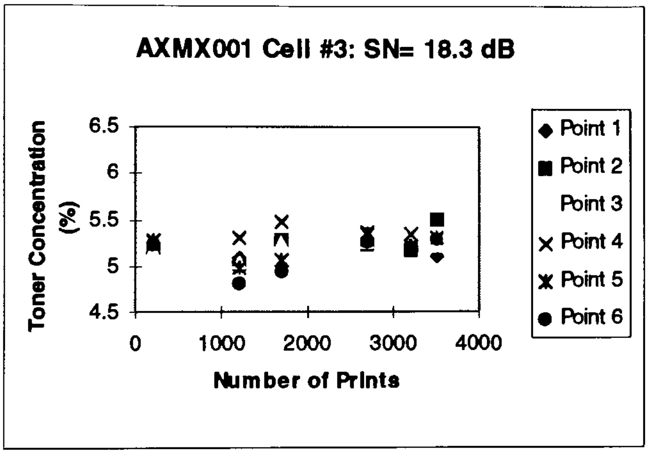


Figure 14
Cell 3 Toner Concentration Plot

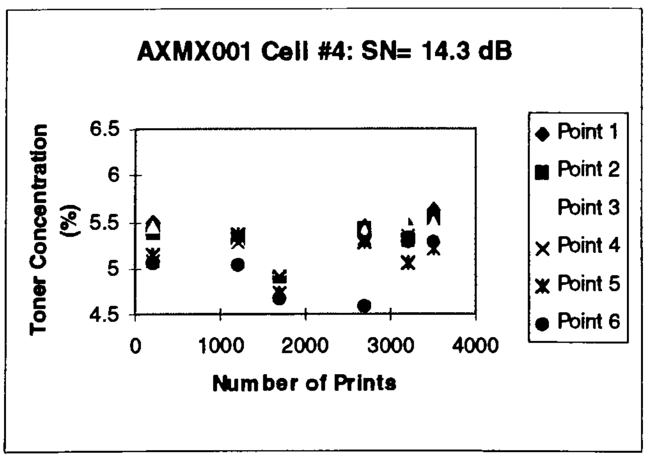


Figure 15
Cell 4 Toner Concentration Plot

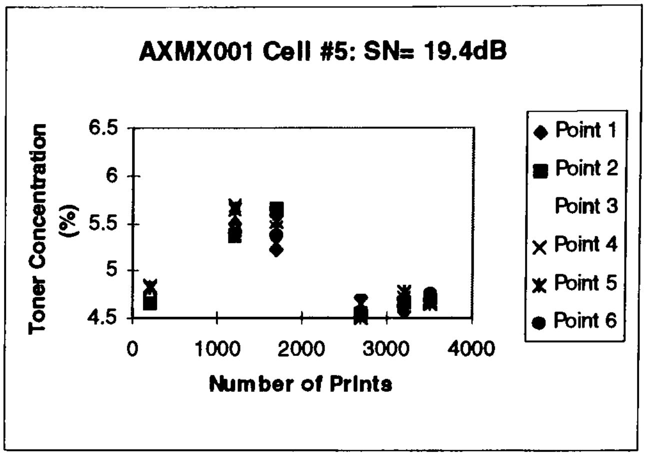


Figure 16
Cell 5 Toner Concentration Plot

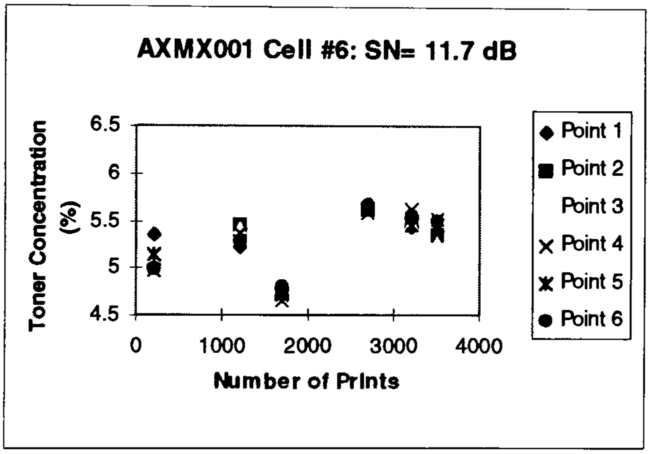


Figure 17
Cell 6 Toner Concentration Plot

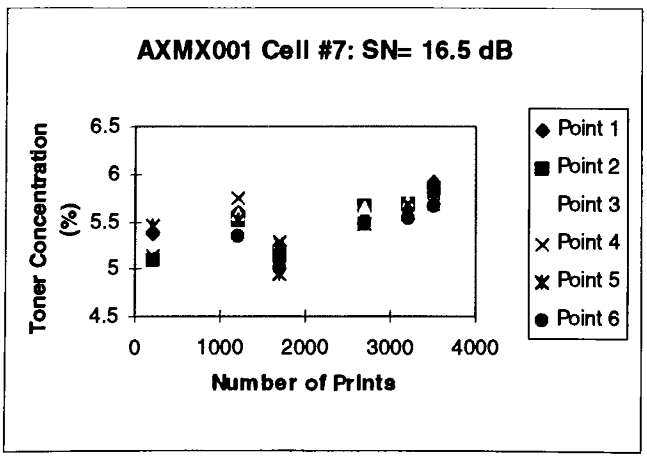


Figure 18
Cell 7 Toner Concentration Plot

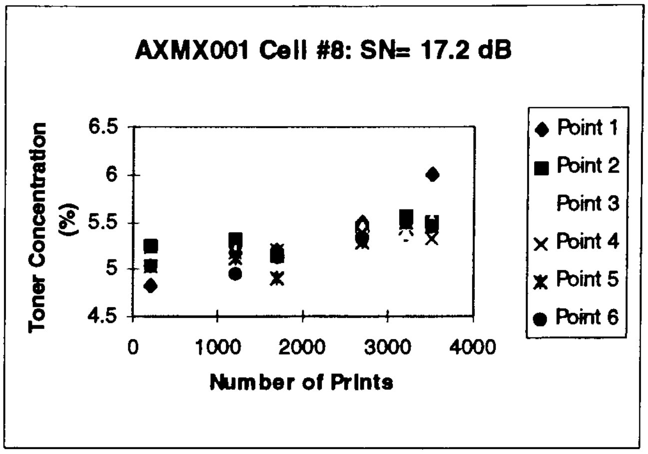


Figure 19
Cell 8 Toner Concentration Plot

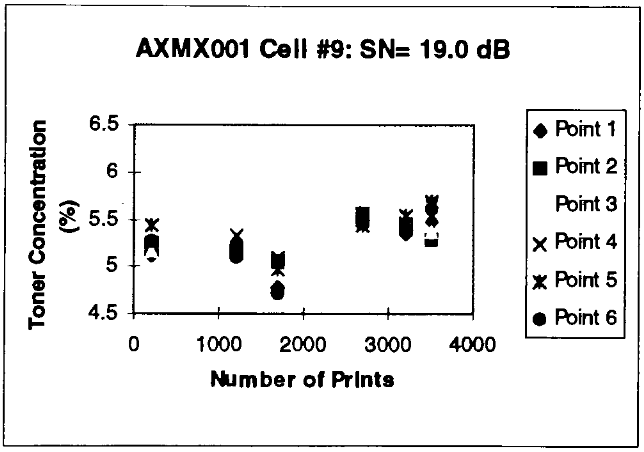


Figure 20
Cell 9 Toner Concentration Plot

The plots are very useful in looking at general trends and conditions of each of the cells. However, the real goal is to determine which control factors are driving the variation in toner concentration and optimize the system. It is difficult to determine the contribution of the control factors to the variation with any test that has more than two or three control factors and more than two levels. To facilitate the analysis, signal to noise ratios are calculated and are used to complete the analysis.

The toner concentration data is summarized in Appendix B. Here each of the toner concentration values for each sample point and each noise is tabulated. In addition, the variance has been calculated for each of the six sample points. The variance is calculated for each noise and replicates. The variance will be used with equation 1.0 (section 2.1.3) to calculate the signal to noise ratio for each cell. Recall that equation 1.0 is as follows:

$$\text{signal to noise ratio} = -10 \operatorname{Log}_{10} (\sigma^2) \qquad (1.0)$$

where

σ^2= variance

In the case of the first cell, the variances are averaged and the value is used in equation 1.0 to calculate the overall signal to noise ratio for that cell. In this case the average variance is 0.02568, this is substituted into equation 1.0 to give a S/N ratio for cell 1 equal to 15.9 dB. The 15.9 dB is a measure of the variation of toner concentration for the cell. It is not intended to measure the variation from noise level to noise level. The variation from noise level to noise level was attributed to an immature toner concentration control system and is an artifact of the control system and not a result of the control factors. If the control system had been functional a nominal the best signal to noise ratio would have been used. The signal to noise ratios for all nine cells are listed in Table 4.

Table 4
Signal to Noise Ratios

Cell	Signal to noise
Cell 1	15.9 dB
Cell 2	19.1 dB
Cell 3	18.3 dB
Cell 4	14.3 dB
Cell 5	19.4 dB
Cell 6	11.8 dB
Cell 7	16.5 dB
Cell 8	17.2 dB
Cell 9	19.0 dB
Overall Ave	16.8 dB

The total decibel range (dB) of the test gives an indication of the ability to distinguish between the cells. The larger the range the better the analysis will be. The large range is desired because it shows that an improvement can be made. If the signal to noise ratios are the same this implies that none of the control factors affect the response and the system is already optimized. The above test shows a total decibel range of about 7.6 dB with the best cell being cell 5 and the worst being cell 6. Although the 7.6 dB is not very large it is adequate to complete the analysis. To determine what caused those cells to be the best and the worst the main effects for the factors must be calculated. The calculation is simply the average of the signal to noise ratios for each cell in which the relevant level is present. The calculation for level 1 (4890 style) of the mix auger design control factors requires the average of the signal to noise ratios for the first three cells to be calculated. The first three cells are averaged since the mix auger , at level 1, appears only in the first three cells. This results in a value of 17.7 dB. Tables 5 and 6 show the main effects for the signal to noise ratio and the response analysis respectively.

Table 5
Signal to Noise Main Effects (TC)

S/N Ratio Factor Effects	Level1	Level2	Level3	Optimum S/N Ratio	Optimum Levels
MixAuger	17.79	15.17	17.57	17.79 dB	1.
PickupAuger	15.57	18.60	16.36	18.60 dB	2.
MixAugerSpeed	14.96	17.48	18.10	18.10 dB	3.
MOR	18.11	15.80	16.61	18.11 dB	1.

Table 6
Mean Response Main Effects (TC)

Mean Factor Effects	Level1	Level2	Level3	Optimum Means	IMR
MixAuger	0.120	0.153	0.122	0.120	-0.011782
PickupAuger	0.153	0.111	0.131	0.110	-0.02108
MixAugerSpeed	0.151	0.129	0.115	0.115	-0.016905
MOR	0.118	0.138	0.139	0.118	-0.013727

The signal to noise factor effects can be easily plotted to observe the data graphically. These plots are shown in Figure 21.

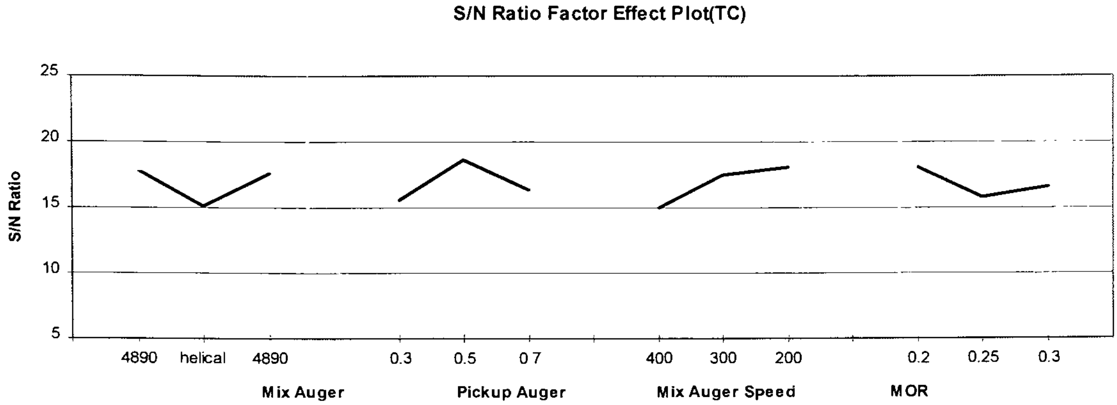


Figure 21

Signal to Noise Factor Effects Plot (TC)

Inspection of Figure 21 quickly shows that there is clearly some internal consistencies within the test. This can be seen in the fact that the levels 1 and 3 for the mix auger control factor are identical and result in similar signal to noise ratios. Visual inspection of the factor effects plot easily indicates what the optimum levels are. The signal to noise ratio was based on minimizing the variance of the toner concentration. Therefore, any level which maximizes the signal to noise ratio will help in minimizing the toner concentration variation. The factor effects plot leads to the following conclusions:

1) Mix auger Design: level 1 and 3 (4890 style) are preferred
2) Pickup auger Design: Level 2 (0.5 pitch/diameter) is preferred
3) Mix auger speed: Level 3 (200 RPM) is preferred
4) MOR : Level 1 (0.2 gm/cm^2) is preferred

The same plot can be made for the response effects. The response effects plots are given in Appendix C. The theoretical reasons for the selction of the specific control factors will be discussed in section 4.2. The selection of the optimum levels is complete but an important piece of information is still missing. To better understand the effects of the control factors on the system it would be beneficial to determine the contribution of each of the control factors on the variation of the system. This will enable making a tradeoff between design and performance. To determine the contributions an analysis of variance (ANOVA) was completed using the information from the factor effects Tables. The ANOVA analysis is listed in Table 7

Table 7
Signal to Noise Ratio ANOVA summary

ANOVA Table		Correction Factor			2553.56	
SNRatios		DOF	SS	MSV	F Ratio	% Contrib
	MixAuger	2	12.72	6.36		24.26%
	PickupAuger	2	14.84	7.42		28.30%
	MixAugerSpeed	2	16.61	8.31		31.68%
	MOR	2	8.27	4.13		15.77%
	Error	0	4.547E-13			

The important part of the ANOVA analysis exists in the last column which gives the percent contribution for each of the control factors. The control factors impact on the toner concentration is described by the percent contribution. In this case the first three control factors account for a major portion of the variation within the test. The error listed can be an important indicator of how much of the variation can not be accounted for within the control factors. However, in the test run, the orthogonal array was “full” ie: no columns left empty. The result of this “full” orthogonal array is that all the variation is assigned to the control factors and it appears that 100% of the variation is due to the four control factors. It is unlikely that this is correct. If the error is significant then the test will not provide verification. The verification is discussed in sections 3.3 and 3.4.

The Taguchi analysis was completed using a Xerox developed piece of software using MS Excel and input from the author. The full analysis and plots can be found in Appendix C.

3.2 Charge Spectography Analysis

The charge spectography was a secondary response to aid in the analysis of the test. The charge data was collected from the magnetic roll(sample points 4,5 and 6) for each of the noise conditions. The charge spectography data gives a good indication of the ability of the system to mix by looking at the charging of the toner within the developer housing. The rationale is that a system that quickly and efficiently mixes the toner will also quickly charge the same toner. The point at which the auger system must be the most efficient is while it is trying to mix the incoming toner while the second noise condition (75% area coverage) is being run. This is a known stress and should give the best indication of the ability of the system to mix and charge the toner. By analyzing the single point the signal to noise ratio range should be maximized. The other two noise conditions are not a stress on the systems ability to charge the toner and the resultant charge spectography data would be tight and narrowed. If this data had been included the result would be a reduced range of signal to noise ratios. This reduced range would make the determination of the contributions difficult. The charge spectography data is summarized in Appendix D.

After inspecting the charge spectography it was decided to only look at the center of the roll just after the replicate for noise 2. The data was not significantly different across the roll and at the end of the 1500 prints of noise level 2 the system should be at steady state and the analysis wouldn't include transients. The relevant data for these points is the mean and standard deviations for the charge/diameter (Q/D) quantity. The data is listed in Table 8.

Table 8
Charge Spectography Means and Standard Deviations

Cell	Means	StdDev
Cell 1	-0.228	0.155
Cell 2	-0.237	0.163
Cell 3	-0.252	0.159
Cell 4	-0.227	0.157
Cell 5	-0.22	0.172
Cell 6	-0.153	0.17
Cell 7	-0.227	0.163
Cell 8	-0.177	0.152
Cell 9	-0.28	0.153

The mean and standard deviations of the Q/D will be used in equation 2.0. The equation is listed below:

$$\text{Signal to noise ratio} = 10 \log_{10} (\mu^2/\sigma^2) \qquad (2.0)$$

where

μ= average Q/D

σ= standard deviation

The above formula is the nominal the best type signal to noise ratio. As the standard deviation in the Q/D increases or the mean decreases the signal to noise ratio will decrease. This will drive to a tight charge distribution with a high average Q/D as the signal to noise ratio is maximized. The signal to noise ratios were calculated and are listed in Table 9.

Table 9
Charge Spectography Signal to Noise Ratios

Cell	SNRatios
Cell 1	3.35 dB
Cell 2	3.25 dB
Cell 3	4.00 dB
Cell 4	3.20 dB
Cell 5	2.14 dB
Cell 6	-0.92 dB
Cell 7	2.88 dB
Cell 8	1.32 dB
Cell 9	5.25 dB
ave	2.72 dB

Inspection of the signal to noise ratios shows that there is about a 6 decibel difference between the worst and the best cells. The toner concentration analysis also showed cell 6 as being the worst performing cell. As with the toner concentration analysis the main effects are calculated . Table 10 shows the main effects for the charge spectography (CSG) signal to noise ratio analysis.

Table 10
Signal to Noise Main Effects (CSG)

S/N Ratio Factor Effects	Level1	Level2	Level3	Optimum S/N Ratio	Optimum Levels
MixAuger	3.53	1.48	3.15	3.53 dB	1
PickupAuger	3.14	2.24	2.78	3.14 dB	1
MixAugerSpeed	1.25	3.90	3.00	3.90 dB	2
MOR	3.58	1.74	2.84	3.58 dB	1

The signal to noise main effects were plotted and are shown in Figure 22.

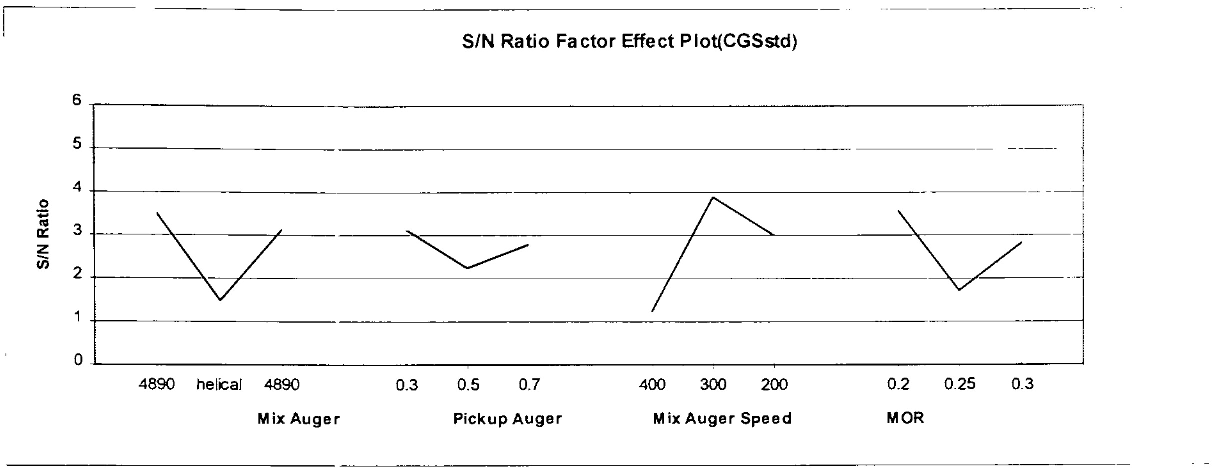


Figure 22

Signal to Noise Factor Effects Plot (CSG)

The factor effects plot indicates what levels are the optimum for the required performance. Since the charge spectography response is a secondary response, the results should be compared to the primary response. Inspection of Figures 21 and 22 show that the two methods agree very closely with each other. There are several points that are consistent and are as follows.

1) Both methods predict the optimum mix auger style to be the 4890 type

2) Both methods predicted the highest auger speed as being the worst

3) Both predict that the MOR should be level 1 (0.2 gm/cm^2)

The two response however, predicted different levels for the last two control factors. If the plots for the Mix auger speed are compared it appears that both plots perform worst at the highest speed (level 1) and then are fairly flat going from level 2 to level 3. In this particular instance it appears that slower is better for the performance and that both analyses agree. The theoretical reasons for the selction of the specific control factors will be discussed in section 4.2.

It appears that there is significant conflict between toner concentration and the charge spectography analysis in predicting the optimum pick-up auger configuration. There are several methods for resolving a conflict between the responses. The first is to review the data to make sure that all the data is correct and that the operator did not change testing procedures for a cell that would influence the data. The data review did not reveal any such problems. A conclusion could be made that neither response has a strong dependency on the control factor and that the responses are flat over the range of control factors tested. In reality it does not matter what level is chosen for the next step in the optimization. The most important part of a Taguchi analysis is to choose an optimum design and predict the expected performance and run the experiment so that the analysis is verified and the results can be used to change the design. The level for the pick up auger was chosen to be 0.5 pitch/diameter ratio. There are two reasons for this choice. The first is that the primary response predicted this level to be optimum and the second reason is based on previous auger designs within the corporation typically are around a 0.5 pitch/diameter ratio. This historical knowledge is what led to the selection of the particular control factors.

The full charge spectography analysis with the ANOVA Tables and additional plots can be found in Appendix E.

3.3 Predicted Optimum

One of the most common mistakes in using Taguchi testing techniques is not to predict the optimum performance and verify the test. The verification of the experiment is done by running the predicted optimum test and verify that the actual signal to noise ratio is equal to the predicted signal to noise ratio. Table 11 shows the optimum levels as predicted by the signal to noise ratios, in addition the levels of the control factors for the starting design are also shown.

Table 11

Optimum and Nominal Control Factor levels

Column	Control Factor Name	Optimum	Nominal
A	MixAuger	4890 style	helical
B	PickupAuger	0.5 P/D	0.5 P/D
C	MixAugerSpeed	200 rpm	400 rpm
D	MOR	0.2 gm/cm2	0.25 gm/cm2

The goal is to predict the expected signal to noise ratio prior to running the optimum conditions. It is also desirable to predict and run the nominal case so that a comparison of the improvement can be made. To calculate the optimum, the values in the factor effects Tables (Tables 5 and 10) are used along with the overall average signal to noise ratio for the test. As a general rule, to avoid over estimation, it is recommended that only half of the control factors be used in the prediction. This general rule was communicated to this author during discussions with Dr. Taguchi and his son Shin Taguchi. The control factors that are typically used are the highest contributors to the variation. In this optimization that would mean that the pick-up auger and mix auger speed would be used. However, due to the contradictions between the responses it was decided to use the mix auger configuration and the mix auger speed for the prediction. The formula for calculating the optimum signal to noise ratio is as follows [3]:

$$s/n_{opt}=(A1-s/n_{ave})+(C3-s/n_{ave})+s/n_{ave}$$

where

s/n_{ave}=average signal to noise ratio

A1,C3 =factor effects signal to noise ratios

In the case of toner concentration the overall mean signal to noise for the test was 16.8 decibels and the factor effect signal to noise ratios were 17.8 and 18.0. The factor effect signal to noise ratios are obtained from the full analyis and can be found in Appendix C. Using the above formula for the optimum signal to noise ratio the expected signal to noise ratio on the verification is 19.1 dB. The same calculation was performed on the charge spectography data and the predicted signal to noise ratios are listed in Table 12.

Table 12

Predicted Signal to Noise Ratios

Column	Control Factor Name	Optimum	Nominal
A	MixAuger	4890 style	helical
B	PickupAuger	0.5 P/D	0.5 P/D
C	MixAugerSpeed	200 rpm	400 rpm
D	MOR	0.2 gm/cm2	0.25 gm/cm2
S/N TC	predicted	19.00 dB	15.2 dB
S/N CGS	predicted	3.78 dB	0 dB

The analysis and optimization is essentially complete. The nine cells were run and the data collected. The data was analyzed and it showed that the control factors did contribute to the variation and an expected performance was predicted. The final step is to run the verification so that the data set can be used.

3.4 Verification Test Results

The verification test is simply running the optimum control factors under the same test conditions as the original nine cells. In addition to the optimum the nominal design was also run so that the total improvement could be quantified in terms of decibel change. The toner concentration plots were created and are shown in Figure 23 and 24 for the Nominal and the Optimum verification runs.

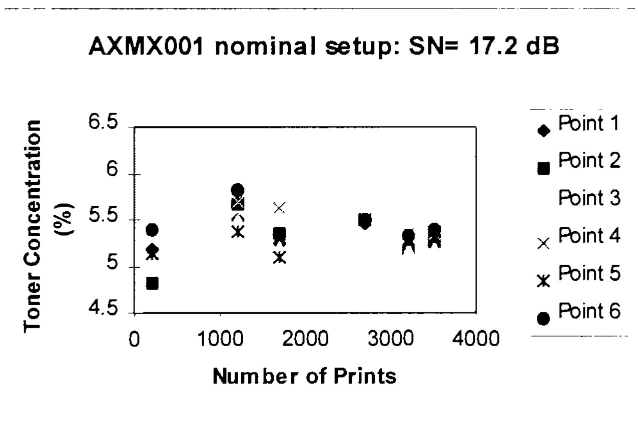


Figure 23

Nominal Toner Concentration Plot

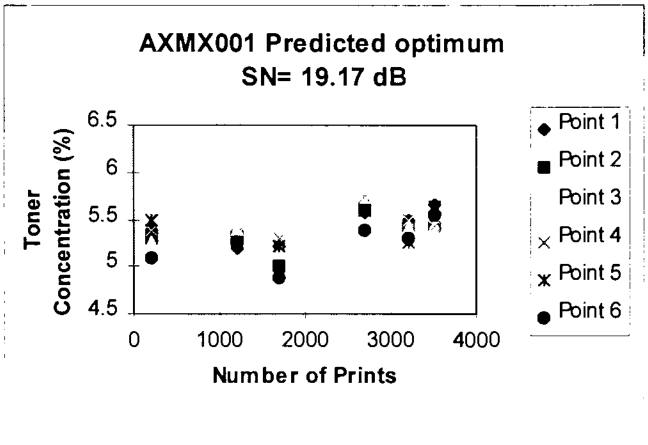


Figure 24
Optimum Toner Concentration Plot

The signal to noise ratio for the two verification cells was calculated and appear on the plots. Inspection of the plots shows that the spread of the data at the optimum is reduced when compared to the nominal test run. The signal to noise ratio calculation shows a 2 dB improvement with the optimum conditions. This will be discussed further in chapter 4.

The charge spectography data for the optimum condition was collected and is shown in Figures 25 and 26.

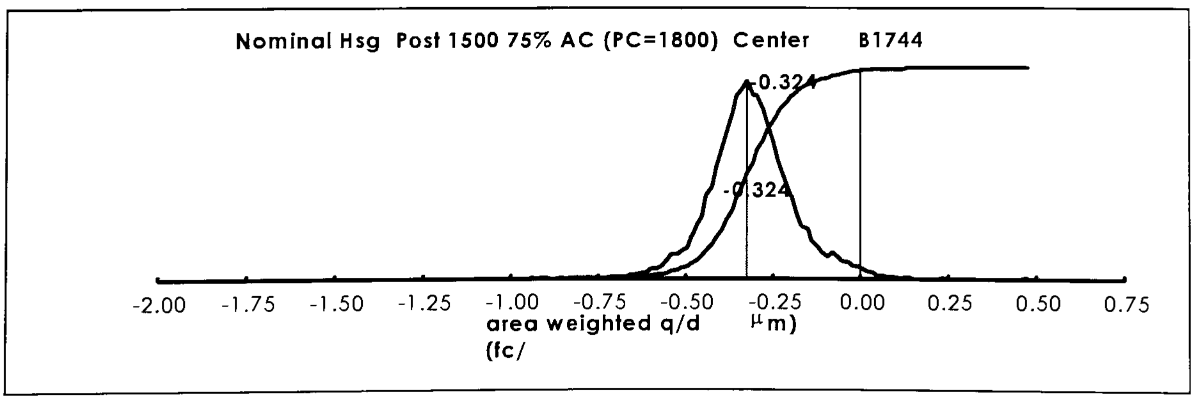


Figure 25
Nominal Charge Spectography Plot

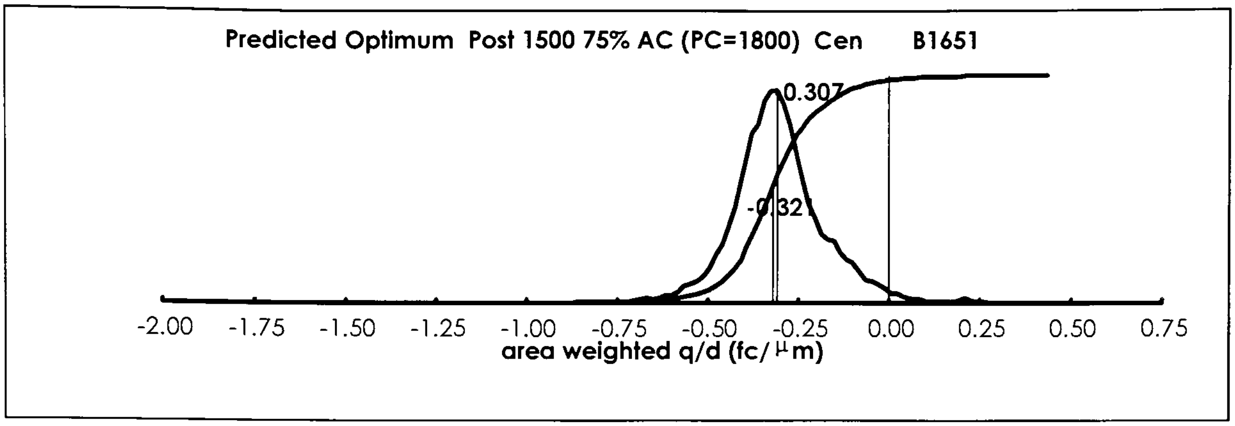


Figure 26
Optimum Charge Spectography Plot

The signal to noise ratios with the predicted and the verified values appear in Table 13.

Table 13

Verification Summary of Signal to Noise Ratios

	Predicted Optimum	Verified Optimum	Predicted Nominal	Verified Nominal
S/N ratio for toner Concentration	19.00 dB	19.17 dB	15.20 dB	17.20 dB
S/N ratio for Charge Spectography	3.78 dB	5.18 dB	0 dB	7.02 dB

The verification data showed that the test did verify and that the control factors that were selected have significant impact on the performance of the system. The verification simply means that the data was used to predict the outcome of a test and the test was run and the signal to noise ratio was the predicted value. The predicted signal to noise ratio for the toner concentration was 19.00 dB and the actual test resulted in a 19.17 dB. The charge spectography predicted a 3.78 dB and the actual data gave 5.18 dB. Since the actual test performed at the expected levels, the test is considered verified.

The nominal configuration results are not as clear and straightforward. The toner concentration prediction was calculated to be 15.2 dB and the actual was 17.2 dB. The charge spectography prediction was for 0 dB and the actual was 7.02 dB. Both methods predicted worse performance that the actual data showed.

The reason for the increased performance of the nominal conditions may be attributed to the condition of the developer material. The original nine cells were run over a period of two months. During this time the developer materials "failed". The failure of the materials became apparent at the end of the test prior to running the verification tests. The failure of the developer materials was the result of the lab temperatures exceeding 90 degrees F and an immature developer materials design. The "failure" was discovered as an unrelated test was being run on the hardware while the data was being analyzed. It was during this unrelated test that the developer material was replaced and the original material discarded. Normally this would call into question the entire validity of the verification. However, the "failure" of the developer materials relates to the ability of the developer material to accept charge. This is why the verification of the charge spectography showed better than expected results. The verifications were run with the nominal case first and then the optimum design. Even though the test is only 3500 prints this is enough to affect the developer material's ability to accept charge and may be the cause of the superior charge spectography performance in the nominal conditions. The toner concentration is solely a measurement of the system to evenly mix the toner and this ability is weakly affected by the developer materials condition. The verification data showed this by having better than expected performance for both the nominal and the optimum tests. The verification data is included in the Appendices A and B.

CHAPTER 4.0 DISCUSSION and CONCLUSIONS

4.1 Principal Component Analysis [5]

The following discussion revolves around a statistical analysis technique that is referred to as Principal Component Analysis. This analysis was suggested and initially completed by Dr. Joseph Voelkel of the Rochester Institute of Technology. The data was then reanalyzed by Christine Keenan of Xerox Corporation. The author has relied heavily on these individuals for this work. The sole purpose of the alternate analysis is to provide additional support for the conclusions that were made from the Taguchi analysis.

A cursory inspection of the raw data doesn't show any blatant trends or easily distinguishable information. Only the signal to noise ratios generated using the Taguchi analysis shows what is really happening The conclusion and the optimization relied solely on the Taguchi analysis. The goal of using the principal component techniques is to use the raw data and determine if the variation seen in the raw data is being affected by the control factors or is it solely due to uncontrolled random variation. The complete analysis is found in Appendices F through M. The complete analysis was done several ways which included using the covariance and correlation matrix methods and with and without averaging the replicates. The different methods were focused on trying to determine if the control factors and the noise factors used within the design optimization are statistically significant.

The analysis treated the Taguchi matrix as one component and the noise variable as the other component. The analysis did not treat the control factors and noise factors as individual quantities. By analyzing the data in this fashion we can determine if the Taguchi matrix component (control factors) or the Noise matrix component (noise factors) had a statistically significant contribution to the variation within the test. Recall the Taguchi matrix consists of four control factors at three levels and the noise factor consisted of one noise at three levels. The principle component analysis treated the nine primary cells along with the two verification and several repeats cells as a single data set. The data set was used to develop the principle components. By using all of the data set to generate the principle components, a better estimation of the principle components value can be made. The principle components are used in an analysis of variation (ANOVA) to analyze the primary nine cells. The example that will be reviewed was completed by determining the principle components using the raw data (versus a normalized data set) The results of the principle components can be found in Table 14.

Table 14
Principal Components Using Raw Data

Eigenvalue	4.7210	0.4778	0.3133	0.1958	0.1812	0.1109
Proportion	0.787	0.080	0.052	0.033	0.030	0.018
Cumulative	0.787	0.866	0.919	0.951	0.982	1.000

Test Point	PC1	PC2	PC3	PC4	PC5	PC6
1	-0.368	0.761	0.493	0.124	-0.107	0.121
2	-0.422	-0.001	-0.556	0.225	-0.084	0.674
3	-0.415	0.252	-0.472	-0.540	-0.125	-0.484
4	-0.425	-0.158	-0.053	0.669	0.317	-0.494
5	-0.415	-0.281	0.317	-0.439	0.636	0.227
6	-0.400	-0.503	0.350	-0.047	-0.679	-0.031

The numbers that are of interest are the Proportion and Cumulative numbers. These quantities are the percentage of variation that is explained by each successive principal component. In this analysis the first three principal components account for about 92% of the variation throughout the six test points in the housing.

The next part of the analysis is to determine the factor(s) that drive the variation. This is accomplished using the analysis of variance technique (ANOVA). The ANOVA that is listed below did not average the replicates. The analysis with the replicates averaged can be found in the Appendices H and I.

Analysis of Variance (Balanced Designs) using L9 with replicates

Factor	Type	Levels	Values
Cell	fixed	9	1 2 3 4 5 6 7 8 9 (nine cells)
Noise	fixed	3	0 15 75 (three noise levels)

Analysis of Variance for Score1

Source	DF	SS	MS	F	P
Cell	8	90.908	11.363	2.91	0.018
Noise	2	26.819	13.409	3.44	0.047
Cell*Noise	16	115.576	7.223	1.85	0.076
Error	27	105.255	3.898		
Total	53	338.557			

Analysis of Variance for Score2

Source	DF	SS	MS	F	P
Cell	8	6.8066	0.8508	2.12	0.069
Noise	2	0.2994	0.1497	0.37	0.692
Cell*Noise	16	6.5392	0.4087	1.02	0.469
Error	27	10.8426	0.4016		
Total	53	24.4878			

Analysis of Variance for Score3

Source	DF	SS	MS	F	P
Cell	8	3.5618	0.4452	1.39	0.244
Noise	2	2.3697	1.1848	3.71	0.038
Cell*Noise	16	3.1283	0.1955	0.61	0.847
Error	27	8.6254	0.3195		
Total	53	17.6852			

The letters DF, SS, MS, F and P are abbreviations for Degrees of Freedom, Sum of the Squares, Mean Square, F statistic and P value. Only the analysis for the first three principal components (Score1,Score2 and Score3) are shown. This was done since the first three account for 92% of the variation and the last two contribute a very small amount to the analysis. The P value is another way of looking at the statistical significance of the analysis. As the value of P gets smaller the higher the statistical significance. The important value to look for is the F statistic which gives an indication of the statistical significance of the data. For this analysis a confidence interval of 90% was used. Given the degrees of freedom, the critical F value, $F_{critical90,}$ for the factor called CELL and the factor called Noise are 1.91 and 2.51 respectively.

The conclusion reached is that the Cell factor (Control factor Matrix) and the Noise factor (Noise factor matrix) are statistically significant at a 90% confidence interval and account for 78.7% of the variation throughout the test. The second principal component indicates the Cell factor to be statistically significant in the 90% confidence interval accounting for another 8% of the variation. The third principal component indicates the Noise Factor to be statistically significant accounting for 5% of the variation bringing the total accountable variation to 92%.

The principal component analysis was completed using a variety of ways trying to poke at the data. Repeatedly the same conclusion is reached and that is the following:

1) The Cell Factor and the Noise factor are significant contributors to the variation that was measured throughout the test.

2) The analysis is not the result of analyzing random noise.

3) Given conclusions 1, 2 and engineering judgement the Taguchi analysis is valid and the optimization will result in improved performance.

4.2 Summary and Conclusions

The Taguchi analysis only gives an indication of the contribution of each of the control factors. It does not explain functionality. There is a theoretical reason for the selection of some of the levels for the control factors.

The analysis predicted the 4890 style mix auger as the best level for minimizing the toner concentration variation. This auger is designed with features that improve the ability of the auger to mix the toner into the developer material. The helical augers are in not designed to mix but to transport the developer material.

The Mix auger speed was selected at the slowest speed as being the best for minimizing the variation. This is maybe a result of the decrease in transport efficiency as the speed is decreased. Typically as the transport efficiency is decreased the mixing of the material from one vane to the next increases which in turn will decrease the variation throughout the housing.

The pick-up auger pitch to diameter selection of the optimum is the 0.5 ratio. As with the MOR there is not a clear theoretical reason for the 0.5 P:D ratio is better than any other. A hypothesis is that the highest P:D did not move the material housing fast enough and resulted in an increase in the toner concentration variation while the smallest P:D ratio did not allow for any mixing within the auger and this caused an increase in the variation. However these hypothesis would require further testing if this knowledge was required.

The selection of the level for the mass on the roll control factor is not clear. The data showed the lowest (0.2 gm/cm^2) and the highest (0.3 gm/cm^2) MORs performing better than the middle MOR. There is not a xerographic process explanation for this result. This lack of explanation is why a design change was not made.

This investigation has optimized a developer housing auger system using Taguchi methodologies. The statement of the problem as it appears in section 1.4 stated that the purpose of the investigation was to optimize the following control factors:

1) The pitch and geometry of the mix auger
2) The pitch of the pick-up auger
3) The revolutions per minute of each auger
4) The mass on the magnetic roll

The following conclusions can be deduced from the results of the experiments and the analyses that have been completed.

1) The pitch and geometry of the mix auger is the 4890 style auger that is shown in Figure 6 on page 28. The percent contribution of the mix auger style on the total variation of the system is about twenty seven percent.

2) The pitch of the pick-up auger was optimal at the 0.5 pitch to diameter ratio. The percent contribution for the pick-up auger is about thirty five percent. The

experiments also reinforced the current Xerox design practice for this type of auger.

3) The revolutions per minute for the augers is 200 RPM for the mix auger which results in a pick-up auger speed of 140 RPM. The percent contribution of the auger speeds is about twenty five percent. Recall that the mix auger speed was the control factor while the pick-up auger speed was an outcome

4) The mass on the magnetic roll is the 0.2 mgs per cm^2. The percent contribution for the mass is about eleven percent.

5) The above control factors resulted in between 2-3 dB improvement over the nominal design. The predicted and verified performance was 19 dB while the nominal design prediction was 15.8 and the actual was 17 dB. The difference between the actual nominal cell and the optimum cell is 1.89 dB and represents about a 50% reduction in the toner concentration variation

6) Taguchi methodologies were successfully employed to optimize a four control factor system using a total of eleven experiments, nine cells and two verification tests.

4.3 Additional Points of Study

Many issues have arisen as a result of this investigation which should be investigated further. The more pressing of these are the following:

1) In the future, a more satisfactory way of completing the optimization would be to use a dynamic signal to noise ratio calculation. The dynamic signal to noise ratio is shown below:

signal to noise = $10 \text{ Log}_{10} (B^2/\sigma^2)$

$y = BM$

where

y= response factor

M=signal factor

B= the slope of the line

The signal factor M is a control factor that is known to give a proportional change in the output of the response y. This technique allows the optimization to take place over an operating range versus a single (static point).

2) As the developer and the toner material formulations change the performance of the system must be checked and reoptimized if the performance is degraded. The affect of the materials design can't be predicted and it is much easier to redesign hardware than to redesign toner formulations.

3) Additional performance enhancement maybe achieved by an investigation of the mix auger design itself. The current investigation used the existing design as is and did not attempt to optimize the mix auger geometry. A Taguchi optimization could easily be employed to change a variety of design features on the mix auger ie: pitch, the flute width, the rpm etc...

5.0 LIST OF REFERENCES

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APPENDIX A
Raw Toner Data

	Type	Spacing	RPM
Auger #1	4890		500
Auger #2	0.3 Pitch/Dia		625
Mag Roll			380
Donor Rolls			458
CPH		0.019"	
DRS		0.041"	

Start	
TC	5.31
Tribo	20.21
At	127.48

Removed 610 grams of developer to obtain the 0.019" CPH

AUGER #1

CELL # 01

Date	Machine Count	umber o Prints	est Pol Cell #	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	CENTER % TC	CENTER Q/M	CENTER At	INBOARD % TC	INBOARD Q/M	INBOARD At	Standard devaition for each noise across each housing
7/10/96	281521	200	A	5.02	14.98	90.18	4.90	15.68	92.48	4.90	15.31	90.26	0.1044
	281626	305	B										
	281726	405	C										
	281826	505	D										
	281926	605	E										
	282026	705	F										
	282526	1205	G	4.96	24.02	143.12	5.16	24.76	152.64	5.14	22.69	139.33	0.1412
	283026	1705	H	5.59	22.39	147.54	5.37	25.12	159.95	5.32	22.71	143.42	0.1514
	283136	1815	I										
	283236	1915	J										
	283326	2005	K										
	283436	2115	L										
	283536	2215	M										
	284036	2715	N	5.90	20.28	140.00	5.69	20.17	134.87	5.74	21.52	145.08	0.0885
	284536	3215	O	5.21	22.23	138.04	5.04	21.07	127.19	5.05	21.32	129.00	0.1144
	284746	3425	P	5.66	17.43	116.03	4.91	19.41	114.67	4.97	19.14	114.18	0.2819
			MAX	5.90	24.02	147.54	5.69	25.12	159.95	5.74	22.71	145.08	
			MIN	4.96	14.98	90.18	4.90	15.68	92.48	4.90	15.31	90.26	
			Average	5.39	20.22	129.15	5.18	21.04	130.30	5.19	20.45	126.88	
			StDev	0.38	3.42	22.00	0.31	3.54	24.83	0.31	2.83	21.29	

MAG ROLL

INBOARD % TC	INBOARD Q/M	INBOARD At	CENTER % TC	CENTER Q/M	CENTER At	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	Documen	Of Prin	Charge Spec File # /CTR/	TC Varian	Tribo Variance	Mag TC Variance
4.97	15.79	94.21	5.18	18.42	113.91	4.96	18.72	111.62	IBLNK.FR	200	6/B1527/	0.010897	2.703226667	0.015433333
5.32	19.69	124.49	5.20	20.57	127.55	5.01	22.11	132.91	ACSE.FR	100	9/B1530/B1531			0.024433333
5.14	21.93	134.64	5.06	23.32	141.21	4.99	23.57	141.21	ACSE.FR	100				0.005633333
5.34	21.75	137.97	5.38	24.49	156.31	5.19	24.16	149.63	ACSE.FR	100				0.010033333
5.52	22.66	147.68	5.42	24.68	158.45	5.32	22.65	143.06	ACSE.FR	100				0.01
5.24	23.83	148.65	5.09	24.82	151.15	5.29	22.24	139.88	ACSE.FR	100				0.010833333
5.24	23.85	148.85	4.95	26.67	158.60	4.89	26.56	156.31	ACSE.FR	500		0.019947	2.509736667	0.035033333
5.51	23.84	155.14	5.34	30.78	195.06	5.16	29.57	182.01	ACSE.FR	500	2/B1533/	0.022937	12.89363	0.030633333
5.57	23.30	152.99	5.40	29.40	188.18	5.40	26.18	167.62	5ACB.FR	100				0.009633333
5.63	23.98	158.94	5.58	28.35	186.52	5.59	24.46	161.28	5ACB.FR	100				0.0007
5.54	21.99	143.70	5.54	28.88	189.00	5.54	25.34	165.83	5ACB.FR	100				0
5.31	23.00	145.05	5.22	29.04	180.52	5.29	25.85	162.58	5ACB.FR	100				0.002233333
5.62	22.38	148.14	5.45	27.91	180.05	5.49	24.63	159.73	5ACB.FR	100				0.0079
5.87	20.84	143.18	5.72	26.64	179.02	5.72	22.46	150.94	5ACB.FR	500		0.007827	5.92463	0.0075
5.20	21.98	136.23	5.04	26.96	162.71	5.31	22.50	141.87	5ACB.FR	500	5/B1536/	0.013097	4.696986667	0.018433333
5.18	20.62	127.50	5.13	24.92	152.89	4.93	22.36	132.47	IBLNK.FR	200	8/B1539/	0.07948	7.068786667	0.0175
5.87	23.98	158.94	5.72	30.78	195.06	5.72	29.57	182.01			Sum of V	0.007593	286.9825764	0.004213651
4.97	15.79	94.21	4.95	18.42	113.91	4.89	18.72	111.62			Sq Root	0.087135	16.9405601	0.064912642
5.39	21.96	140.46	5.29	25.99	163.82	5.26	23.96	149.93			Signal to N	1.059806	-1.228927765	1.187670713
0.23	2.07	15.54	0.22	3.30	23.39	0.25	2.48	17.07			Signal to N	2.119612	-2.45785553	2.375341427

APPENDIX A

	Type	Spacing	RPM
Auger #1	4890		400
Auger #2	Pitch/Dia.		250
Mag Roll			380
Donor Rolls			458
CPH			0.022"
DRS			0.050"

NOTE: Problems with density on prints at 2F point. Had to rerun – was okay then – WHY ??
Also ::: Because nobody knows how to fix the Chillers, the temp / RH went from 72F/50%RH at the start of the test to 84F / 43% R down every day this week.

AUGER #1

CELL # 02

Date	Machin Count	umber Prints	est Poi Cell #	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	CENTER % TC	CENTER Q/M	CENTER At	INBOARD % TC	INBOARD Q/M	INBOARD At	Standard devaition for each noise acroos the housing
6/28/96	274163	200	A	5.19	19.22	118.98	5.09	18.81	114.53	5.24	17.61	109.97	0.0695
	274268	305	B										
	274368	405	C										
	274468	505	D										
	274568	605	E										
	274773	810	F										
	275273	1310	G	5.21	21.53	133 67	5.35	20.31	128.92	5.12	21.51	131.54	0.1111
	275773	1810	H	5.19	21.60	133.76	5.19	22.84	141.26	5.06	21.90	132.67	0.1387
	275883	1920	I										
	275983	2020	J										
	276083	2120	K										
	276183	2220	L										
	276283	2320	M										
	276783	2820	N	5.47	23.07	149.25	5.49	23.26	150.68	5.48	20.92	135.65	0.0518
	277283	3320	O	6.02	21.91	153 72	5.64	22.26	147.77	5.72	21.78	146.37	0.1634
	277493	3530	P	5.64	22.75	151.10	5.85	22.52	154.17	5.76	22.50	152.17	0.0941
			MAX	8.02	23.07	153.72	5.85	23.28	154.17	5.78	22.50	152.17	
			MIN	5.19	19.22	118.98	5.09	18.81	114.63	5 06	17.61	109.97	
			Averag	5.45	21.68	140.08	5.44	21.67	139.59	5.40	21.04	134.73	
			StDev	0.33	1 36	13.55	0.28	1.73	15.18	0.30	1.76	14.61	

MAG ROLL

INBOARD % TC	INBOARD Q/M	INBOARD At	CENTER % TC	CENTER Q/M	CENTER At	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	Documen	Of Prin	Charge Spec File # /CTR/	TC Variance	Tribo Variance	Mag TC Variance
5.27	18.67	117.07	5.28	19.73	123.89	5.22	18.52	115.21	IBLNK.FR	200	2/B1453/	0 00483	0 50864	0.001033333
5.50	20 11	130.76	5.39	22.05	149.34	5.29	21.80	137.09	ACSE.FR	100	5/B1456/B1457			0.011033333
5.53	19.20	125.38	5.48	22.30	144.47	5.57	21.16	139.05	ACSE.FR	100				0.002033333
5.39	19.89	127.11	5.27	22.82	142.97	5.26	21.51	134.69	ACSE.FR	100				0.005233333
5.70	18.11	121.42	5.65	23.34	155.32	5.51	21.10	137.32	ACSE.FR	100				0.0097
5.81	17.39	118.45	5.71	22.46	150.81	5.66	21.36	142 23	ACSE.FR	100				0.005833333
5.35	20.04	127.26	5.12	25.38	155.23	5.13	22.99	141.03	ACSE.FR	500		0.012346667	3 91072	0.0169
5.40	21.09	134.94	5.36	22.57	143.55	5.09	24.13	146.86	ACSE.FR	500	6/B1459/	0.01923	1.16187	0.028433333
5.31	23.36	147.38	5.27	27.51	172.39	5.14	25.70	157.80	SACB.FR	100				0.0079
5.41	22.06	141.42	5.39	28.18	179.99	5.36	24.76	157.40	SACB.FR	100				0.000633333
5.55	23.21	151.93	5.52	26.86	175.08	5.48	24.19	156.63	SACB.FR	100				0.001233333
5.40	23.41	149.83	5.33	27.44	173.59	5.31	23.40	147.67	SACB.FR	100				0.002233333
5.27	26.93	168.79	5.61	28.35	187.35	5.57	27.63	181.49	SACB.FR	100				0.034533333
5.55	23.55	154.23	5.43	27.66	177.71	5.40	24.32	155.65	SACB.FR	500		0 00268	4.870266667	0.0063
5.84	23.66	161.92	5.56	27.81	182.53	5.69	25.42	170.11	SACB.FR	500	2/B1463/	0.02671	5.749586667	0 019633333
5.72	23.81	159.98	5.59	24.20	159.38	5.77	24.88	168.44	IBLNK.FR	200	5/B1466/	0.008856667	0.998826667	0.008633333
5.84	28.83	188.78	5.71	28.35	187.35	5.77	27.83	181.48						
5.27	17.39	117.07	5.12	19.73	123.89	5.09	18.52	115.21						
5.50	21.53	139.87	5.44	24.92	160.85	5.40	23.30	149.29						
0.18	2.81	18.72	0.18	2.78	18.02	0.21	2.28	18.28						

	TC Variance	Tribo Variance	Mag TC Variance
Sum of V	0.001344609	74.67728642	0.00313807
Sq Root	0.036668911	8.641602075	0.056018479
Signal to N	1.435701989	-0.936594264	1.251668686
Signal to N	2.871403979	-1.873168528	2.503337373

	Type	Spacing	RPM
Auger #1	4890		300
Auger #2	0.7 Pitch/Dia.		125
Mag Roll			380
Donor Rolls			458
CPH			0.026"
DRS			0.059"

AUGER #1

CELL #03

Date	Machine Count	umber o Prints	est Poi Cell #	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	CENTER % TC	CENTER Q/M	CENTER At	INBOARD % TC	INBOARD Q/M	INBOARD At	Standard devaition for each noise across the housing
6/25/96	267093	216	A	5.19	20.36	125.96	5.17	21 71	133 86	5.16	20.98	129.34	0.0534
	267203	310	B										
	267303	410	C										
	267403	510	D										
	267503	610	E										
	267603	710	F										
	268103	1210	G	5.07	27.55	167.36	5.01	26.55	159 44	5.04	25 99	156 92	0 1560
	268603	1710	H	5.28	21.99	138 19	5.27	23 29	146 07	5.26	23 63	147 92	0 1882
	268713	1820	I										
	268813	1920	J										
	268913	2020	K										
	269013	2120	L										
	269113	2220	M										
	269613	2720	N	5.25	24.35	152.10	5.23	25.12	156 57	5.26	23.31	145 83	0.0553
	270113	3220	O	5.27	23.43	146 94	5.16	23.14	142.55	5.33	23.42	148.37	0.0779
	270323	3430	P	5.10	22.71	138.48	5.49	21.40	138.96	5.21	22 22	137.90	0.1280
			MAX	5.28	27.55	167.36	5.49	26.55	159.44	5.33	25.99	156.92	
			MIN	5.07	20.36	125 96	5 01	21.40	133.86	5.04	20.98	129.34	
			Averag	5.19	23.40	144.84	5.22	23.54	146.24	5.21	23 26	144.38	
			StDev	0.09	2.44	14.18	0.16	1.99	10.01	0.10	1.67	9.55	

MAG ROLL

INBOARD % TC	INBOARD Q/M	INBOARD At	CENTER % TC	CENTER Q/M	CENTER At	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	Documen	Of Prin	Charge Spec File # /CTR/	TC Varian	Tribo Variance	Mag TC Variance
5.28	21.83	137.18	5.28	26 44	166.11	5.23	24 05	149.85	IBLNK.FR	200	4/B1415/	0 002857	5.173256667	0 000833333
5.38	25.51	162.83	5.26	27.71	173.57	5.01	28.57	171.65	ACSE.FR	100	7/B1418/B1419			0 035633333
5.47	24.58	158.95	5.28	29.30	183.92	5.26	27.28	170.76	ACSE.FR	100				0 013433333
5.58	27.38	180.24	5.43	29.22	187.86	5.40	28.13	180.09	ACSE.FR	100				0.0093
5.67	24.49	163.33	5.37	30.11	191.89	5.38	26.12	166.78	ACSE.FR	100				0.029033333
5.71	26.13	175.21	5.51	28.55	185.83	5.43	27.63	177.77	ACSE.FR	100				0.0208
5.29	26.67	167 73	4.97	29.75	177.59	4.81	29.96	174.15	ACSE.FR	500		0 024337	2 92559	0.059733333
5.47	24.64	159.36	5.05	31.22	188.82	4.94	29.51	175.16	ACSE.FR	500	0/B1421/	0.035417	13 99322667	0 078233333
5.41	25.38	162.76	5.28	32.76	205.80	5.35	26.99	171.40	5ACB.FR	100				0 004233333
5.57	28.64	188.28	5.50	30.40	197.51	5.41	28.53	182.93	5ACB.FR	100				0 006433333
5.67	27.14	180.94	5.55	29.45	192.77	5.56	29.92	196.17	5ACB.FR	100				0 004433333
5.66	25.55	170.25	5.63	29.49	195.43	5.62	27.69	183.29	5ACB.FR	100				0 000433333
5.65	27.72	184.34	5.55	28.92	189.37	5.48	28.24	182.91	5ACB.FR	100				0 0073
5.37	25.73	163.74	5.33	30.49	192.88	5.25	29.19	182.40	5ACB.FR	500		0.003057	8 06855	0.003733333
5.34	25.57	162.03	5.20	30.04	186.08	5.18	26 25	162.29	5ACB.FR	500	3/B1424/	0.006067	7 027896667	0.0076
5.30	22.75	143.24	5.29	24.83	156.18	5.28	25.26	158.52	IBLNK.FR	200	6/B1427/	0.016377	2 30867	1E-04
5.71	28.64	188.28	5.83	32.76	205.80	5.82	29.96	198.17						
5.28	21.83	137.18	4.97	24.83	156.18	4.81	24.05	149.85			Sum of V	0.002169	350.9548418	0.012705622
5 49	25.61	166.28	5.34	29.29	185.73	5.29	27.71	174.13			Sq Root	0.046574	18.73378877	0.112719219
0.15	1.76	13.79	0.18	1.85	12.32	0.22	1.67	11.24			Signal to	1.331859	-1.272625619	0.948002031
											Signal to N	2.663717	-2.545251238	1.896004062

	Type	Spacing	RPM
Auger #1			
Auger#2			
Mag Roll			
Donor Roll			
CPH			
DRS			

AUGER #1

CELL #4

Date	Machine Count	Number of Prints	Test Point	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	CENTER % TC	CENTER Q/M	CENTER At	INBOARD % TC	INBOARD Q/M	INBOARD At	Standard devaition for each noise across housing
6/14/96	258371	200	A	5.48	18.69	121.10	5.38	19 13	122 02	5.45	16 06	103 63	0.196312676
	258476	305	B										
	258576	405	C										
	258676	505	D										
	258776	605	E										
	258876	705	F										
	259376	1205	G	5.32	22.49	142.20	5.32	23 15	146.30	5.29	24.27	152 61	0.117770964
	259876	1705	H	4.95	23 52	139.94	4.91	24.44	144.53	5.00	24.44	146 54	0.128944432
	259991	1820	I										
	260091	1920	J										
	260191	2020	K										
	260291	2120	L										
	260391	2220	M										
	261891	3720	N	5.44	19.38	124 73	5.42	21 54	138 30	5.39	22.39	143.28	0.324160454
	262391	4220	O	5.36	19.74	125.44	5.30	20.76	130.83	5.47	21 07	136.25	0.136088207
	261601	3430	P	5.61	19.43	128.36	5.54	20.11	131.57	5.46	19.51	126.06	0 173982758
			MAX	5.61	23.52	142.20	5.54	24.44	146.30	5.47	24.44	152.61	
			MIN	4.95	18.69	121.10	4.91	19.13	122.02	5.00	16.06	103 63	
			Average	5.36	20.54	130.30	5 31	21.52	135.59	5.34	21.29	134 73	
			Stdev	0.22	1.97	8 69	0.21	1.97	9.22	0.18	3 18	17.76	

MAG ROLL

INBOARD % TC	INBOARD Q/M	INBOARD At	CENTER % TC	CENTER Q/M	CENTER At	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	Documen	0f Prin	Charge Spec File # /CTR/O	TC Varian	Tribo Variance	Mag TC Variance
5.07	19.92	120.93	5.15	23.11	142.18	5.05	22.53	136.25	IBLNK.FR	200		0 038539	6.804746667	0.002885333
5.09	22.26	135.68	5.07	25 12	152.59	4.96	23 09	137 55	ACSE.FR	100				0.0049
5.50	22.11	143.64	5.09	26.58	161.84	4.93	25.37	150.37	ACSE.FR	100				0.086433333
5.29	24.85	156.36	5.04	25.88	156.26	5.11	24.46	149.41	ACSE.FR	100				0.016633333
5.42	22.68	145.51	5.16	28 33	174.41	5.10	24.17	147.29	ACSE.FR	100				0.028933333
5.55	22.67	148.42	5.36	26.93	171.38	5.18	23.99	148.33	ACSE.FR	100				0.034233333
5.28	23.23	145.92	5.35	26.75	169.76	5.03	24.84	149.81	ACSE.FR	500		0.01387	2.369536667	0.0283
4.91	25.21	148.99	4.74	32.62	187.22	4.67	28.60	162.17	ACSE.FR	500		0.016627	12.17825667	0.015233333
5.05	25.10	151.89	5.07	30.48	185.03	5.02	26.09	157.04	5ACB.FR	100				0.000633333
5.14	24.04	147.48	4.97	30.65	183.07	5.07	24.23	147.15	5ACB.FR	100				0.0073
5.47	22.92	148.40	5.35	28.60	181.70	5.19	23.08	142.79	5ACB.FR	100				0.019733333
5.23	23.75	148.08	5.31	28.33	182 83	5.29	25.67	161.44	5ACB.FR	100				0.001733333
5.20	21.75	134 91	5.25	27.92	174.47	5.17	24.31	150.07	5ACB.FR	100				0.001633333
5.32	22.87	144.63	5.28	27.76	174.45	4.59	27.24	152.29	5ACB.FR	500		0.10508	10.91496	0.168433333
5.34	21.75	137.98	5.06	29.52	178.91	5.27	22.91	143.61	5ACB.FR	500		0.01852	12.52147	0.021233333
5.22	20 91	130.12	5.21	27.39	170.16	5.27	21.28	133.36	IBLNK.FR	200		0.03027	9.048576667	0.001033333
5.55	25.21	156.36	5.38	32.62	187.22	5.29	28.60	162.17			Sum of V	0.014255	558.0295191	0.040092205
4.91	19.92	120.93	4.74	23.11	142.18	4.59	21.28	133.36			Sq Root	0.119395	23.62264844	0.20023038
5.25	22.88	143.06	5.15	27.87	171.64	5.06	24.49	148.06			Signal to N	0.923015	-1.373328587	0.698470028
0.178118874	1.476987362	8.992081609	0 166768302	2.295048928	12.71402054	0.198490134	1.832073052	8.189450302			Signal to N	1.846029	-2.746657173	1 396940056

	Type	Spcaing	RPM
Auger #1			
Auger #2			
Mag Roll			
Donor Roll			
CPH			
DRS			

AUGER #1

	Machine	umber o	est Poi	OUTBOARD			CENTER			INBOARD			Standard devaition for each noise across each housing
Date	Count	Prints	Cell #	% TC	Q/M	At	% TC	Q/M	At	% TC	Q/M	At	
				CELL #5									
6/6/96	251404	200	5A	4.75	23.89	137 37	4.65	22.77	128.67	4.74	23.23	133.31	0.0765
	251509	305	5B										
	251609	405	5C										
	251709	505	5D										
	251809	605	5E										
	251909	705	5F										
	252409	1205	5G	5.48	25.90	167 91	5.37	26.00	165.53	5.40	25.08	160.43	0.1339
	252910	1706	5H	5.21	28.04	174 11	5.64	29.96	179.10	5.41	30.61	196.31	0.1538
6/7/96	252920	1716	AM										
	253020	1816	5I										
	253120	1916	5J										
	253220	2016	5K										
	253320	2116	5L										
	253420	2216	5M										
	253920	2716	5N	4.71	27.51	157.08	4.54	28.04	155.36	4.81	26 29	152 63	0.1191
	254420	3216	5O	4.56	27.54	153.21	4.65	28.45	160.70	4.64	27.85	156.94	0 0752
	254630	3426	5P	4.60	27.09	151.73	4.64	24.75	139.59	4.61	26 87	150.78	0.0591
			MAX	5.48	28.04	174.11	5.64	29.96	179.10	5.41	30.61	198.31	
			MIN	4.56	23.89	137.37	4.54	22.77	128.67	4.61	23.23	133 31	
			Average	4 89	26.66	156.90	4.92	26 66	154.83	4 94	26.66	158.40	
			STDEV	0.37	1.54	12.96	0.47	2 65	18.19	0.37	2.51	20.81	

MAG ROLL

INBOARD			CENTER			OUTBOARD					Charge Spec File #			
% TC	Q/M	At	% TC	Q/M	At	% TC	Q/M	At	Documen	0f Pri	/CTR/	TC Varian	Tribo Variance	Mag TC Variance
4.83	25.57	149.02	4.81	26 44	153.48	4.65	28.03	158.30	IBLNK.FR	200	7/B1338/	0 005857	4.183296667	0.009733333
5.04	26.36	159.25	4.95	29.18	173.69	4.81	28.93	168.20	ACSE.FR	100	0/B1341/B1342			0.013433333
5.07	28.19	170.96	5.32	29.71	187 61	5.36	28.50	181.28	ACSE.FR	100				0.0247
5.36	27.64	175.86	5.41	31 44	201.40	5.10	29.88	182.37	ACSE.FR	100				0.0277
5.37	28.94	184.36	5.32	30.12	190.28	5.04	28.73	173.44	ACSE.FR	100				0.031633333
4.72	28.39	162.23	4.79	34.06	197.11	4.50	35.54	195.34	ACSE.FR	100				0.0229
5.67	26.40	176.14	5.64	32.15	213.48	5.38	29.77	189.88	ACSE.FR	500		0.01792	7 72736	0.025433333
			5.42	34.42	220.94	5.37	30 82	196.31	ACSE.FR	500	3/B1344/	0.02365	5 3649	0.00125
			5.52	31.51	205.53				No Document					
5.45	23 66	152 54	5.59	29.81	196.55	5.48	25.95	168.14	SACB.FR	100				0.005433333
5.46	25.95	167.67	5.39	28.53	182 44	5.37	29.93	190.52	SACB.FR	100				0.002233333
5.32	26.22	165.77	5.33	28.29	179.06	5.24	28.30	176.56	SACB.FR	100				0.002433333
5.25	26.52	165.72	5.24	29.62	184.88	5.06	28.80	174.60	SACB.FR	100				0.011433333
5.41	28.69	183.92	5.30	30.12	189.69	5.38	29.66	189.31	SACB.FR	100				0.003233333
4.55	26.12	144.84	4.51	31.18	171.92	4.56	33.02	183.41	SACB.FR	500		0.014187	7.825746667	0.0007
4.71	28.31	161.66	4.78	28.48	164.59	4.63	31.00	174.47	SACB.FR	500	6/B1347/	0.005657	1 51339	0.005633333
4.69	27.46	156.32	4.65	30.44	171.89	4.76	32.06	184.51	IBLNK.FR	200	9/B1350/	0 003497	7 064296667	0.0031
5.67	28.94	184.36	5.64	34.42	220.94	5.48	35.54	198.31				0.00116	142.2190996	0.003954769
4.55	23.66	144.84	4.51	26.44	153.48	4.50	25.95	158.30				0.034062	11.92556496	0.062886955
5.13	26.96	165.08	5.14	29.97	183.87	5.02	29.87	179.36				1.467727	-1.076478962	1.20143943
0.350339971	1.43847	11.84043	0.3544	1.80848	15.400621	0.3431	2 30874	10.10185						

	Type	Spacing	RPM
Auger #1			
ASuger #2			
Mag Roll			
Donor Roll			
CPH			
DRS			

AUGER #1

CELL #6

Date	Machine Count	umber o Prints	est Poin Cell #	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	CENTER % TC	CENTER Q/M	CENTER At	INBOARD % TC	INBOARD Q/M	INBOARD At	Standard devaition for each noise across each housing
6/11/96	254940	200	6A	5.34	17.50	110.92	3.74	21.82	103.52	5.18	18.23	112.68	0.5799
	255045	305	6B										
	255145	405	6C										
	255245	505	6D										
	255345	605	6E										
	255445	705	6F										
	255945	1205	6G	5.22	28.31	176.19	5.45	26.75	172.41	5.41	24.59	157.69	0.0900
	256445	1705	6H	4.77	31.21	180.20	4.73	30.86	177.07	4.86	28.92	169.59	0.0747
	256555	1815	6I										
	256655	1915	6J										
	256755	2015	6K										
	256855	2115	6L										
	256955	2215	6M										
	257455	2715	6N	5.67	26.18	174.51	5.61	25.43	168.14	5.67	26.74	178.24	0.0403
	257966	3226	6O	5.43	28.21	181.49	5.50	26.02	169.14	5.47	25.39	164.30	0.0692
	258166	3426	6P	5.33	25.84	163.47	5.34	25.60	162.20	5.26	25.61	159.53	0.1003
			MAX	5.67	31.21	181.49	5.61	30.86	177.07	5.67	28.92	178.24	
			MIN	4.77	17.50	110.92	3.74	21.82	103.52	4.86	18.23	112.68	
			Average	5.29	26.21	164.46	5.06	26.08	158.75	5.31	24.90	157.01	
			Stdev	0.30	4.68	27.00	0.72	2.90	27.50	0.28	3.60	22.95	

MAG ROLL

INBOARD % TC	INBOARD Q/M	INBOARD At	CENTER % TC	CENTER Q/M	CENTER At	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	Documen	Of Prin	Charge S /CTR/O	Housing TC Varian	Housing Tribo Variance	Mag TC Variance
4.96	16.93	100.96	5.13	21.52	131.83	4.99	18.24	109.19	IBLNK.FR	200	4/B1355/	0.33632	4.39972	0.008233333
5.12	23.22	142.21	5.22	24.86	154.58	5.09	26.08	158.72	ACSE.FR	100	7/B1358/B1359			0.004633333
5.34	25.98	164.67	5.44	25.17	161.97	5.35	27.87	177.13	ACSE.FR	100				0.003033333
5.40	24.62	157.64	5.34	27.16	172.10	5.35	26.67	169.38	ACSE.FR	100				0.001033333
5.48	26.63	172.64	5.64	26.68	177.21	5.44	27.77	178.81	ACSE.FR	100				0.0112
5.22	27.59	171.55	5.06	29.04	175.99	5.12	31.76	194.24	ACSE.FR	100				0.006533333
5.37	28.16	179.41	5.27	29.85	187.06	5.28	28.17	176.90	ACSE.FR	500		0.0081067	3.195776667	0.003033333
4.65	27.58	155.86	4.70	33.57	191.41	4.80	30.42	176.48	ACSE.FR	500	0/B1361/	0.0055767	4.211106667	0.005833333
5.06	28.09	170.20	4.99	36.04	215.95	4.92	32.29	191.00	5ACB.FR	100				0.0049
5.48	28.66	185.71	5.46	33.66	216.81	5.34	29.81	189.02	5ACB.FR	100				0.005733333
5.65	27.46	182.54	5.51	31.00	201.87	6.02	26.56	186.37	5ACB.FR	100				0.069433333
5.61	27.71	183.07	5.50	31.86	207.03	5.65	30.86	205.05	5ACB.FR	100				0.006033333
5.52	27.18	177.15	5.54	33.13	216.80	5.50	25.96	168.70	5ACB.FR	100				0.0004
5.57	26.38	173.34	5.62	30.22	200.17	5.66	28.13	187.50	5ACB.FR	500		0.0016267	3.00804	0.002033333
5.61	25.44	168.07	5.45	28.90	186.50	5.56	25.25	165.62	5ACB.FR	500	3/B1364/	0.0047867	2.56507	0.0067
5.52	25.79	168.16	5.44	28.98	186.49	5.48	24.60	159.31	IBLNK.FR	200	6/B1367/	0.01007	2.258626667	0.0016
5.65	28.66	185.71	5.64	36.04	216.81	6.02	32.29	205.05			Sum of V	0.1133349	68.03322711	0.005276892
4.65	16.93	100.96	4.70	21.52	131.83	4.80	18.24	109.19			Sq Root	0.3366525	8.248225694	0.072642221
5.35	26.09	165.82	5.33	29.47	186.49	5.35	27.53	174.59			Signal to	0.4728181	-0.916360536	1.138810888
0.2786	2.831407	20.62861	0.255896	3.7919	23.9258	0.312937	3.3908	21.65617			Signal to N	0.9456362	-1.832721072	2.277621776

	Type	Spacing	RPM
Auger #1	890 Style		300
Auger #2	3 Ptich/Dia		350
Mag Roll			380
Donor Rolls			458
CPH		0.022"	
DRS		0.050"	

AUGER #1

CELL #7

Date	Machin Count	umber o est Prints	Pol Cell #	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	CENTER % TC	CENTER Q/M	CENTER At	INBOARD % TC	INBOARD Q/M	INBOARD At	Standard devaition for each noise across each housing
6/20/96	262106	200	A	5.37	18.73	119.32	5.10	18.13	110.52	5.77	16.33	110.48	0.2675
	262211	305	B										
	262311	405	C										
	262411	505	D										
	262511	605	E										
	262611	705	F										
	263111	1205	G	5.60	23.28	153.60	5.52	24.26	158.14	5.57	23.75	156.05	0.1277
	263611	1705	H	5.23	25.50	158.90	5.13	26.15	160.44	5.36	25.19	160.16	0.1597
	263721	1815	I										
	263821	1915	J										
	263921	2015	K										
	264021	2115	L										
	264121	2215	M										
	264621	2715	N	5.60	24 20	159 77	5.66	22 54	150 17	5.63	20.94	138.85	0.0915
	265121	3215	O	5.65	23.52	153.40	5.68	22.87	152 81	5.70	21.75	145.73	0 0640
	265332	3426	P	5.90	21.17	146 09	5.82	20.67	140.99	5.73	20.29	136.60	0.0903
			MAX	5.90	25.50	159.77	5.82	26.15	160.44	5.77	25.19	160.16	
			MIN	5.23	18.73	119.32	5.10	18.13	110.52	5.36	16.33	110.48	
			Average	5.56	22.73	148.51	5.49	22.44	145.51	5.63	21.38	141.31	
			StDev	0.23	2 42	15.12	0.30	2 79	18.45	0.15	3.07	17.72	

MAG ROLL

INBOARD % TC	INBOARD Q/M	INBOARD At	CENTER % TC	CENTER Q/M	CENTER At	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	Documen	Of Prin	Charge Spec File # /CTR/	TC Varian	Tribo Variance	Mag TC Variance
5.14	19.36	118.93	5.44	20.64	132.98	5.08	20.76	126.23	IBLNK.FR	200	4/B1385/	0 071547	2 775016667	0.0372
5.40	20.93	133.99	5.21	22.91	142.18	4.83	24.18	140.98	ACSE.FR	100	7/B1388/B1389			0.084233333
5.53	22.81	148.94	5.68	23.99	160.17	5.37	23 73	151.24	ACSE.FR	100				0 024033333
4.99	23 96	143.65	5.25	24.72	154.60	4.82	24.13	140.43	ACSE.FR	100				0.0469
5.17	25.50	157.38	5.05	24.12	145.83	4.98	25.87	154.73	ACSE.FR	100				0 009233333
5.62	23.28	154.12	5.27	25.91	162.48	5.06	27.39	165.95	ACSE.FR	100				0.080033333
5.74	24.76	166.78	5.51	27.56	179.44	5.35	29.40	186.68	ACSE.FR	500		0.016297	5 905936667	0.038433333
5.27	25.82	161.81	4.95	31.33	186.35	5.00	30.48	183.01	ACSE.FR	500	0/B1391/	0 025507	7 496696667	0.029633333
5.25	26.69	166.83	5.21	32.73	203.15	5.19	30.04	185.87	5ACB.FR	100				0 000933333
5.24	25.76	160.76	5.14	33.12	203.39	5.15	30.12	185.33	5ACB.FR	100				0.003033333
5.36	28.11	178.71	5.33	30.89	195.56	5.41	27.92	178.96	5ACB.FR	100				0.001633333
5.16	25.78	158.85	5.12	34.16	209.01	5.06	28.84	174.82	5ACB.FR	100				0.002533333
5.28	26.76	168.14	5.39	31.61	202.03	5.23	28.13	175.24	5ACB.FR	100				0.0067
5.47	25.79	166.84	5.47	31.43	203.33	5.46	27.20	175.61	5ACB.FR	500		0.008377	13 84984	3.33333E-05
5.68	23.42	156.39	5.58	29.36	193.11	5.54	23.89	156.14	5ACB.FR	500	3/B1394/	0 004097	7 10771	0.0052
5.68	22.13	147.74	5.74	27.69	186.55	5.66	22.73	151.47	IBLNK.FR	200	6/B1397/	0.00815	7.422146667	0.001733333
5.74	28.11	178.71	5.74	34.16	209.01	5.66	30.48	186.88			Sum of	0.006188	396.2071369	0.020196243
4 99	19.36	118.93	4.95	20.64	132.98	4.82	20.76	126.23			Sq Root	0.078667	19.90495257	0.142113488
5.37	24.43	155.62	5.33	28.26	178.76	5.20	26.55	164.54			Signal to	1.104208	-1.298961147	0.847364703
0.22	2.33	14.63	0.23	4.15	25.27	0.25	2.99	18.96			Signal to N	2.208417	-2.597922294	1.694729405

APPENDIX A

	Type	Spacing	RPM
Auger #1	4890		500
Auger #2	.5 Pitch/Dia		318
Mag Roll			380
Donor Rolls			458
CPH			0.026"
DRS			0.059"

START	
TC	5.32
Tribo	21.26
At	134.40

AUGER #1

CELL #08

Date	Machine Count	umber o Prints	est Pol Cell #	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	CENTER % TC	CENTER Q/M	CENTER At	INBOARD % TC	INBOARD Q/M	INBOARD At	Standard devaition for each noise across each housing
7/9/96	277673	200	A	4.81	17.94	104.22	5.23	16.14	100.56	5.02	15.84	95.36	0.1329
	277778	305	B										
	277878	405	C										
	277978	505	D										
	278078	605	E										
	278178	705	F										
	278678	1205	G	5.18	21.33	131.75	5.29	23.19	145.93	5.17	23.89	147.45	0.1125
	279178	1705	H	5.20	22.78	141.20	5.14	24.52	150.57	4.93	24.75	146.85	0.1344
	279288	1815	I										
	279388	1915	J										
	279488	2015	K										
	279588	2115	L										
	279688	2215	M										
	280188	2715	N	5.50	22.48	146.03	5.42	21.78	139.73	5.43	20.38	131.08	0.0795
	280688	3215	O	5.37	21.19	134.97	5.55	20.26	132.65	5.38	19.07	121.72	0.0729
	280898	3425	P	5.99	17.53	122.55	5.50	20.69	134.42	5.52	18.12	118.16	0.2320
			MAX	5.99	22.78	146.03	5.55	24.52	150.57	5.52	24.75	147.45	
			MIN	4.81	17.53	104.22	5.14	16.14	100.56	4.93	15.84	95.36	
			Average	5.34	20.54	130.12	5.36	21.10	133.98	5.24	20.34	126.77	
			StDev	0.39	2.26	15.03	0.16	2.90	17.72	0.24	3.43	19.68	

MAG ROLL

INBOARD % TC	INBOARD Q/M	INBOARD At	CENTER % TC	CENTER Q/M	CENTER At	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	Documen	Of Prin	Charge Spec File # /CTR/	TC Varian	Tribo Variance	Mag TC Variance
5.03	17.12	103.18	5.02	19.23	115.75	5.02	18.69	112.57	IBLNK.FR	200	0/B1501/	0.0176567	1.870386667	3.33333E-05
5.26	19.96	124.90	5.14	21.45	131.80	5.15	20.77	127.81	ACSE.FR	100	3/B1504/B1505			0.004433333
5.18	20.58	127.26	5.23	21.61	134.57	5.16	21.70	133.67	ACSE.FR	100				0.0013
5.19	20.15	124.62	5.03	24.29	146.39	4.93	22.04	130.73	ACSE.FR	100				0.0172
5.29	20.97	131.83	5.19	24.85	153.70	5.10	24.64	150.35	ACSE.FR	100				0.009033333
5.27	22.24	139.39	5.19	25.33	156.82	5.16	23.44	144.44	ACSE.FR	100				0.003233333
5.18	22.56	139.33	5.11	29.51	180.14	4.95	24.25	144.25	ACSE.FR	500		0.0126667	8.040896667	0.0139
5.19	25.22	156.23	4.89	29.25	172.22	5.12	24.42	149.37	ACSE.FR	500	6/B1507/	0.0180567	4.704266667	0.024633333
5.30	23.49	147.92	5.12	31.56	193.12	5.28	24.30	152.66	SACB.FR	100				0.009733333
5.30	22.17	139.58	5.15	29.61	182.03	5.17	23.15	142.86	SACB.FR	100				0.006633333
5.17	21.98	135.56	5.19	29.56	182.81	5.22	24.22	150.64	SACB.FR	100				0.000633333
5.18	22.43	138.54	5.19	30.04	185.89	5.19	23.98	148.43	SACB.FR	100				3.33333E-05
5.35	22.24	141.31	5.20	28.67	177.68	5.18	23.57	145.79	SACB.FR	100				0.008633333
5.39	21.52	137.48	5.28	25.79	161.95	5.32	23.33	147.47	SACB.FR	500		0.00632	3.494706667	0.0031
5.49	23.99	155.76	5.50	25.52	165.86	5.50	23.30	151.32	SACB.FR	500	9/B1510/	0.00531	6.002856667	3.33333E-05
5.32	21.15	133.72	5.45	21.28	137.27	5.45	21.64	139.52	IBLNK.FR	200	2/B1513/	0.0538167	3.146776667	0.005633333
5.49	25.22	158.23	5.50	31.56	193.12	5.50	24.64	152.66			Sum of V	0.0037626	148.4339566	0.001464273
5.03	17.12	103.18	4.89	19.23	115.75	4.93	18.69	112.57			Sq Root	0.0613402	12.18334751	0.038265825
5.26	21.74	136.04	5.18	26.10	161.13	5.18	22.97	141.99			Signal to N	1.212255	-1.085766632	1.417188923
0.11	1.85	12.76	0.15	3.79	22.82	0.15	1.62	[illegible]			Signal to N	2.4245099	-2.171533264	2.834377847

	Type	Spacing	RPM
Auger #1	4890		400
Auger #2	.7 Pitch/Dia		166
Mag Roll			380
Donor Rolls			458
CPH			0.018"
DRS			0.041"

AUGER #1

Date	Machin Count	umber o Prints	est Pol Cell #	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	CENTER % TC	CENTER Q/M	CENTER At	INBOARD % TC	INBOARD Q/M	INBOARD At	Standard devaition for each noise across each housing
				CELL #09									
6/26/96	270533	200	A	5.11	18.47	112.77	5.20	18.58	115.16	5.16	15.82	97.48	0.1101
	270638	305	B										
	270738	405	C										
	270838	505	D										
	270938	605	E										
	271038	705	F										
	271538	1205	G	5.25	21.18	132.48	5.16	21.81	134.42	5.08	23.02	139.82	0.0999
	272038	1705	H	4.77	23.54	135.74	5.04	23.38	141 20	4.96	24.09	143.56	0.1476
	272148	1815	I										
	272248	1915	J										
	272348	2015	K										
	272448	2115	L										
	272548	2215	M										
	273048	2715	N	5.52	20.75	135.25	5.55	21.83	143.02	5.41	21.68	139 05	0.0550
	273548	3215	O	5.35	23.43	148.75	5.42	21.43	137.58	5.46	20.97	135.60	0.0665
	273758	3425	P	5.47	19.81	128 21	5.28	19.47	122.19	5.37	21.42	136.53	0.1562
			MAX	5.52	23.54	148.75	5.55	23.38	143.02	5.46	24.09	143.56	
			MIN	4.77	18.47	112.77	5.04	18.58	115.16	4.96	15.82	97.48	
			Average	5.25	21.20	132.20	5.28	21.08	132.26	5.24	21.17	132.01	
			StDev	0.28	2.00	11.74	0.18	1.75	11.16	0 20	2.86	17.14	

MAG ROLL

INBOARD % TC	INBOARD Q/M	INBOARD At	CENTER % TC	CENTER Q/M	CENTER At	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	Documen	0f Prin	Charge Spec File # /CTR/	TC Varian	Tribo Variance	Mag TC Variance
5.23	16.74	104.35	5.43	20.91	134.47	5.25	20.92	130 66	IBLNK.FR	200	2/B1433/	0 01212	4.383906667	0.012133333
5.63	19.62	129.98	5.75	20.80	140 42	5.52	22.51	146.79	ACSE.FR	100	5/B1436/B1437			0.013233333
5.36	19.57	124.45	5.40	23.88	152.80	5.19	20.66	127.90	ACSE.FR	100				0.012433333
5.04	20.51	123.92	5.12	25.16	154.03	4.87	23.39	137.32	ACSE.FR	100				0.0163
5.26	22.21	139.05	5.19	26.05	161.34	5.09	23.24	141.56	ACSE.FR	100				0.0073
5.32	21.37	135.01	5.18	23.90	147.80	5.14	23 70	145.61	ACSE.FR	100				0.008933333
5.33	24.51	155.24	5.13	26.98	165.35	5.08	23.94	145.62	ACSE.FR	500		0 0099767	4.352146667	0.0175
5.09	24.98	152.04	4.96	28.85	172.05	4.72	25.90	148 04	ACSE.FR	500	8/B1439/	0 0217867	4.225146667	0.035233333
5.02	25.83	155.62	4.87	29.87	175.41	4.89	29.57	5.14	SACB.FR	100				0.006633333
5.13	26 89	164.90	5.19	29.37	181.76	5.16	27.91	171 84	SACB.FR	100				0.0009
5.23	27.67	172.50	5.23	28.03	174.58	5.12	27.58	168.73	SACB.FR	100				0.004033333
5.36	26.17	166.37	5.23	28.73	179.00	5.28	29.79	186.91	SACB.FR	100				0.0043
5.43	27.44	176.56	5.26	29.15	182.49	5.26	29.37	183.80	SACB.FR	100				0.009633333
5.50	24.39	158.60	5.43	26.03	167.29	5.45	28.65	184.63	SACB.FR	500		0.0030267	9 294896667	0.0013
5.44	23.56	151.81	5.54	26.75	175.02	5.38	22.89	145.97	SACB.FR	500	1/B1442/	0.0044167	4.196416667	0.006533333
5.63	25.14	166.61	5.67	25.93	172.94	5.60	26.86	177.15	IBLNK.FR	200	4/B1445/	0.0243867	10.62627	0.001233333
5.63	27.87	176.56	5.75	29.87	182.49	5.60	29.79	186.91						
5.02	16.74	104.35	4.87	20.80	134.47	4.72	20.66	5.14			Sum of V	0.0013445	272.9343136	0.002641614
5 31	23.54	148.56	5.29	26.27	164.80	5.19	25.43	146.73			Sq Root	0.0366669	16.52072376	0.051396638
0.19	3.21	20.41	0.24	2.81	14.87	0.24	3.13	42.62			Signal to	1.4357254	-1.21802907	1.289065285
											Signal to N	2.8714507	-2.436058139	2.578130569

APPENDIX A

	Type	Spacing	RPM
Auger #	4890		300
Auger #	.5 Pitch/Dia.		170
Mag Roll			380
Donor Rolls			458
CPH		0.018"	
DRS		0.041"	

	Start
TC	5.35
Tribo	27.85
At	149.11

AUGER #1

Date	Machin Count	umber o Prints	est Poi Cell #	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	CENTER % TC	CENTER Q/M	CENTER At	INBOARD % TC	INBOARD Q/M	INBOARD At	Standard devaition for each noise across each housing
				CELL #Predicted Optimum Setup									
8/12/96	313716	3730	Q	5.38	17.44	111.23	5.31	17.15	108.31	5.25	15.97	99.78	0.1371
	313921	3935	R										
	314021	4035	S										
	314121	4135	T										
	314221	4235	U										
	314321	4335	V										
	314821	4835	W	5.20	23.91	148.19	5.33	22.66	143.50	5.38	21.29	135.71	0.0725
	315321	5335	X	5.22	25.15	156.37	5.01	25.42	152 70	5.19	24 07	149 05	0.1573
	311801	1815	I										
	311901	1915	J										
	312001	2015	K										
	312101	2115	L										
	312201	2215	M										
	312701	2715	N	5.58	21.20	139.43	5.61	21.44	141.67	5.75	20.66	138.77	0.1333
	313201	3215	O	5.48	20.37	131 90	5.41	20.61	132.04	5.41	19.70	126.29	0.0918
	313411	3425	P	5.65	19.44	129.23	5.42	22.11	141.94	5.42	20.33	130.47	0.1105
			MAX	5.65	25.15	156.37	5.61	25.42	152.70	5.75	24.07	149.05	
			MIN	5.20	17.44	111.23	5.01	17.15	108.31	5.19	15.97	99.78	
			Average	5.55	19.95	130 60	5.45	20 44	131.75	5.51	20.39	132.29	
			StDev	0.11	0.89	6.87	0.29	1.77	12.01	0.33	2.13	12.34	

MAG ROLL

INBOARD % TC	INBOARD Q/M	INBOARD At	CENTER % TC	CENTER Q/M	CENTER At	OUTBOARD % TC	OUTBOARD Q/M	OUTBOARD At	Documen	Of Prin	Charge S /CTR/	TC Varian	Tribo Vari	Mag TC Variance
5.38	19.69	125 64	5.49	20.59	133.55	5.09	21.56	131 38	IBLNK.FR	200		0 018787	4 833627	0 0427
5.24	19.35	120.75	5.01	22.00	132.20	4.85	20.74	121.37	ACSE.FR	100				0.038433333
5.25	20.66	129.07	5.05	23.57	142.71	5.15	22 54	138.59	ACSE.FR	100				0.01
5.44	20.95	134.83	5.34	24.05	152.51	5.29	21 98	138.29	ACSE.FR	100				0.005833333
5.74	21.00	141.52	5.58	23.50	154.52	5.44	23.92	153.96	ACSE.FR	100				0.022533333
5.45	23.32	150.45	5.33	25.12	159.07	5.20	26 43	163.85	ACSE.FR	100				0.015633333
5.37	25.74	163.92	5.25	27.09	169.33	5.26	27.48	171.97	ACSE.FR	500		0 005257	6 18715	0.004433333
5.30	26.33	165.80	5.21	28.02	174.06	4.88	30.79	181.06	ACSE.FR	500		0 02475	5 90716	0.0489
5.34	23.20	147.19	5.10	31.64	192.98	5.15	30.24	186.08	5ACB.FR	100				0.016033333
5.37	24.11	153.46	5.27	29.92	157.65	5.37	26.61	169.52	5ACB.FR	100				0.003333333
5.33	27.81	176.01	5.25	30.47	190.56	5.28	26.65	167.25	5ACB.FR	100				0.001633333
5.46	24.87	160.78	5.41	30.25	193.99	5.51	26.84	174.61	5ACB.FR	100				0.0025
5.49	24.27	157.54	5.24	30.84	192.36	5.34	25.76	163.29	5ACB.FR	100				0.015833333
5.75	21.73	146 55	5.59	29.73	195.92	5.39	25.17	160.86	5ACB.FR	500		0.017777	12 42862	0.032533333
5.49	21.53	139.75	5.26	28.51	178.58	5.31	22.95	144.80	5ACB.FR	500	3/B1654/	0 008427	10 58354	0.014633333
5.43	22.25	143.00	5.64	23.70	157.27	5.56	21.15	117.67	IBLNK.FR	200	6/B1657/	0.0122	2.301907	0.011233333
5.75	27.81	176.01	5.64	31.64	195.92	5.56	30.79	186.08						
5.24	19.35	120.75	5.01	20 59	132.20	4.85	20.74	117.67						
5.43	22.93	147.27	5.31	26.81	167.33	5.25	25.05	155.28						
0.15	2.46	15.38	0.19	3.57	21.84	0.20	3.10	20.97						

	Type	Spacing	RPM
Auger #	.5 Pitch/Dia		400
Auger #	.5 Pitch/Dia		400
Mag Roll			380
Donor Rolls			458
CPH		0.022"	
DRS		0.050"	

	Start
TC	5.23
Tribo	23.62
At	147.09

Repeat of Cell # 04:
75 degrees F/ 43% Relative Humidity

325557

				AUGER #1									
	Machine	umber o	est Poi	OUTBOARD			CENTER			INBOARD			Standard devaition for each noise across each housing
Date	Count	Prints	Cell #	% TC	Q/M	At	% TC	Q/M	At	% TC	Q/M	At	
				CELL nominal Conditions									
8/19/96	325757	200	A	5.18	19.63	121.27	4.82	20.17	117.37	5.07	19.48	118.25	0.1925
	325862	305	B										
	325962	405	C										
	326062	505	D										
	326162	605	E										
	326262	705	F										
	326762	1205	G	5.49	27.10	175.90	5.68	25 22	168.39	5.49	27.55	178 73	0.1642
	327262	1705	H	5.25	28.73	179.66	5.36	27.67	176.04	5.20	29.15	180.73	0 1813
	327372	1815	I										
	327472	1915	J										
	327572	2015	K										
	327672	2115	L										
	327772	2215	M										
	328272	2715	N	5.45	25.69	165.68	5.49	27.32	177.37	5.59	25.73	169.50	0.0464
	328772	3215	O	5.20	26.03	161 49	5.17	25 06	154.62	5.16	26.42	162.66	0.0873
	328982	3425	P	5.32	24.07	152.03	5.27	24.87	155.86	5.19	24.37	150.84	0.0742
			MAX	5.49	28.73	179.66	5.68	27.67	177.37	5.59	29.15	180.73	
			MIN	5.18	19.63	121.27	4.82	20.17	117.37	5.07	19.48	118.25	
			Averag	5.32	25.21	159.34	5.30	25.05	158.28	5.28	25 45	160.12	
			StDev	0.13	3.14	21 14	0.29	2.68	22.25	0 21	3.34	23.26	

MAG ROLL														
INBOARD			CENTER			OUTBOARD					Charge		TC	
% TC	Q/M	At	% TC	Q/M	At	% TC	Q/M	At	Documen	Of Prin	/CTR/	C Varianc	Tribo Variance	Mag TC Variance
5.14	19.02	116.71	5.01	20.55	123.43	5.40	19.24	123.03	IBLNK.FR	200	7/B1738/	0.04	0.33	0.039433333
5.22	21.78	135.46	5.04	23.30	140.77	5.39	22.34	142.86	ACSE.FR	100	0/B1741/B1742			0.030633333
5.24	23.50	146.74	5.13	25.91	158.72	5.16	25.13	154.91	ACSE.FR	100				0.003233333
5.46	24.48	158.21	5.35	26.09	165.80	5.28	25.79	161.91	ACSE.FR	100				0.008233333
5.46	25.17	162.48	5.43	27.24	175.21	5.60	24.73	163.15	ACSE.FR	100				0.008233333
5.39	26.09	168.77	5.22	28.48	177.22	5.42	27.39	175.94	ACSE.FR	100				0.011633333
5.69	26.17	175.08	5.37	29.14	185.71	5.81	27.38	186.35	ACSE.FR	500		0.03	1.77	0.051733333
5.62	26.67	176.44	5.09	33.31	202.75	5.35	29.63	188.19	ACSE.FR	500	3/B1744/	0.03	5 21	0.070233333
5.24	30.07	187.65	5.27	33.89	212.64	5.30	30.91	194.54	5ACB.FR	100				0.0009
5.48	29.44	190.81	5.25	34.02	212.69	5.30	30.62	193.01	5ACB.FR	100				0.014633333
5.43	29.42	189.30	5.42	33.94	217.89	5.33	32.68	206.91	5ACB.FR	100				0.003033333
5.47	29.07	187.94	5.46	32.45	209.61	5.29	31 50	198.24	5ACB.FR	100				0.010233333
5.39	28.23	180.51	5.16	33.28	204.98	5.36	30.12	191.67	5ACB.FR	100				0.015633333
5.49	25.22	163.64	5.51	29.51	192.16	5.50	27.43	178.17	5ACB.FR	500		0.00	2.56	0.0001
5.36	25.37	161.34	5.28	30.08	188.96	5.34	26.09	165.44	5ACB.FR	500	6/B1747/	0.01	3.31	0.001733333
5.35	24.72	156.98	5.37	28.99	184.60	5.39	25.82	164.96	IBLNK.FR	200	9/B1750/	0.01	3.32	0.0004
5.89	30.07	190.81	5.51	34.02	217.89	5.81	32.68	208.91						
5.14	19.02	116.71	5.01	20.55	123.43	5.16	19.24	123.03						
5.40	25.90	166.00	5.27	29.39	164.56	5.39	27.30	174.33						
0.15	2.98	20.70	0.15	4.06	27.04	0.15	3.57	22.35						

APPENDIX B
Summarized Toner Concentration Data

Summarized Toner Concentration Data

Cell 1	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Variance of TC	StdDEV
200	5.02	4.9	4.9	4.97	5.18	4.97	0.0108	0.103923
1200	4.96	5.16	5.14	5.24	4.95	4.89	0.019947	0.141233
1700	5.59	5.37	5.32	5.51	5.34	5.16	0.022937	0.151449
2700	5.9	5.69	5.74	5.87	5.72	5.72	0.007827	0.088468
3200	5.21	5.04	5.05	5.2	5.04	5.31	0.013097	0.114441
3500	5.66	4.91	4.97	5.18	5.13	4.93	0.07948	0.281922

Cell 2	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Variance of TC	StdDEV
200	5.19	5.09	5.24	5.27	5.28	5.22	0.00483	0.089498
1200	5.21	5.36	5.12	5.35	5.12	5.13	0.012347	0.111116
1700	5.19	5.19	5.08	5.4	5.36	5.09	0.01923	0.138672
2700	5.47	5.49	5.48	5.55	5.43	5.4	0.00268	0.051769
3200	6.02	5.64	5.72	5.84	5.56	5.69	0.02671	0.163432
3500	5.76	5.85	5.76	5.72	5.59	5.77	0.007337	0.085654

Cell 3	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Variance of TC	StdDEV
200	5.19	5.17	5.16	5.28	5.28	5.23	0.002857	0.053448
1200	5.07	5.01	5.04	5.29	4.97	4.81	0.024337	0.156002
1700	5.28	5.27	5.26	5.47	5.05	4.94	0.035417	0.168193
2700	5.25	5.23	5.26	5.37	5.33	5.25	0.003057	0.055287
3200	5.27	5.16	5.33	5.34	5.2	5.18	0.006067	0.077689
3500	5.1	5.49	5.21	5.3	5.29	5.28	0.016377	0.127971

Cell 4	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Variance of TC	StdDEV
200	5.48	5.38	5.45	5.07	5.15	5.05	0.036227	0.195516
1200	5.32	5.32	5.29	5.28	5.36	5.03	0.01367	0.117771
1700	4.95	4.91	5	4.91	4.74	4.67	0.016627	0.128944
2700	5.44	5.42	5.39	5.32	5.28	4.59	0.10508	0.32416
3200	5.36	5.3	5.47	5.34	5.08	5.27	0.01852	0.136068
3500	5.61	5.54	5.46	5.22	5.21	5.27	0.03027	0.173963

Cell 5	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Variance of TC	StdDEV
200	4.75	4.65	4.74	4.83	4.81	4.65	0.005657	0.076529
1200	5.46	5.37	5.4	5.67	5.64	5.38	0.01792	0.133866
1700	5.21	5.64	5.41	5.45	5.52	5.37	0.020987	0.144688
2700	4.71	4.54	4.81	4.65	4.51	4.68	0.014187	0.119108
3200	4.56	4.65	4.54	4.71	4.78	4.63	0.005657	0.075211
3500	4.6	4.64	4.61	4.69	4.65	4.76	0.003497	0.059133

Cell 6	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Variance of TC	StdDEV
200	5.34	3.74	5.18	4.96	5.13	4.99	0.33632	0.579931
1200	5.22	5.45	5.41	5.37	5.27	5.28	0.008107	0.090037
1700	4.77	4.73	4.68	4.65	4.7	4.8	0.005577	0.074677
2700	5.67	5.61	5.67	5.57	5.62	5.68	0.001627	0.040332
3200	5.43	5.5	5.47	5.61	5.45	5.68	0.004787	0.069186
3500	5.33	5.34	5.26	5.52	5.44	5.48	0.01007	0.100349

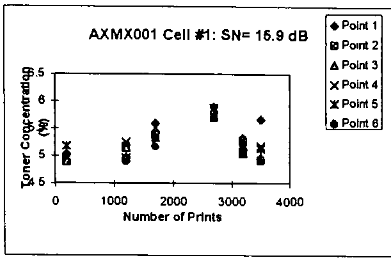
Cell 7	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Variance of TC	StdDEV
200	5.37	5.1	5.77	5.14	5.44	5.08	0.071547	0.267482
1200	5.6	5.52	5.57	5.74	5.51	5.35	0.016297	0.127658
1700	5.23	5.13	5.36	5.27	4.95	5	0.025507	0.159708
2700	5.6	5.68	5.63	5.47	5.47	5.46	0.008377	0.091524
3200	5.65	5.68	5.7	5.68	5.68	5.54	0.004097	0.064005
3500	5.9	5.82	5.73	5.68	5.74	5.68	0.00815	0.090277

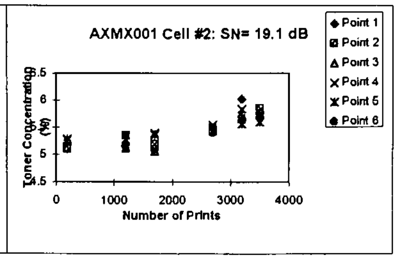
Cell 8	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Variance of TC	StdDEV
200	4.81	5.23	5.02	5.03	5.02	5.02	0.017657	0.132878
1200	5.18	5.29	5.17	5.18	5.11	4.95	0.012667	0.112546
1700	5.2	5.14	4.93	5.19	4.89	5.12	0.018057	0.134375
2700	5.5	5.42	5.43	5.39	5.28	5.32	0.00632	0.079498
3200	5.37	5.55	5.36	5.49	5.5	5.5	0.00531	0.07287
3500	5.99	5.5	5.52	5.32	5.45	5.45	0.053817	0.231984

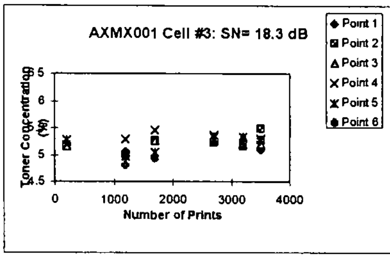
Cell 9	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Variance of TC	StdDEV
200	5.11	5.2	5.16	5.23	5.43	5.25	0.01212	0.110091
1200	5.25	5.16	5.08	5.33	5.13	5.08	0.009977	0.099883
1700	4.77	5.04	4.96	5.09	4.96	4.72	0.021787	0.147503
2700	5.52	5.55	5.41	5.5	5.43	5.45	0.003027	0.055015
3200	5.35	5.42	5.46	5.44	5.54	5.38	0.004417	0.088468
3500	5.47	5.28	5.37	5.63	5.67	5.6	0.024367	0.156162

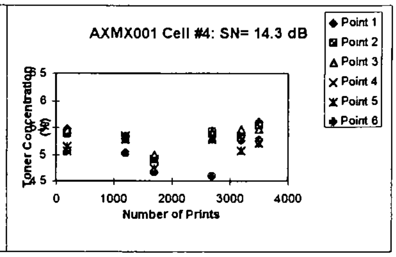
Verif 4 nominal cell	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Variance of TC	StdDEV
200	5.18	4.82	5.07	5.14	5.14	5.4	0.03503	0.187163
1200	5.49	5.68	5.49	5.69	5.37	5.81	0.026977	0.164246
1700	5.25	5.36	5.2	5.62	5.09	5.35	0.032657	0.181264
2700	5.45	5.49	5.59	5.49	5.51	5.5	0.00215	0.046366
3200	5.2	5.17	5.16	5.36	5.28	5.34	0.007617	0.087274
3600	5.32	5.27	5.19	5.35	5.37	5.39	0.00551	0.074229

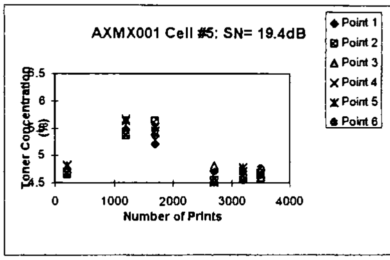
Predicted Opt	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Variance of TC	StdDEV
200	5.38	5.31	5.25	5.36	5.49	5.09	0.018787	0.137064
1200	5.2	5.33	5.38	5.37	5.25	5.26	0.005257	0.072503
1700	5.22	5.01	5.19	5.3	5.21	4.88	0.02475	0.157321
2700	5.58	5.61	5.75	5.75	5.59	5.39	0.017777	0.133329
3200	5.48	5.41	5.41	5.49	5.26	5.31	0.008427	0.091797
3500	5.65	5.42	5.42	5.43	5.64	5.56	0.0122	0.110454

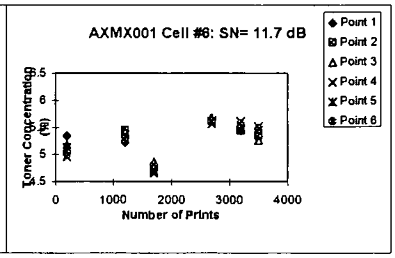

AXMX001 Cell #1: SN= 15.9 dB
Toner Concentration (%)
Number of Prints
Point 1
Point 2
Point 3
Point 4
Point 5
Point 6

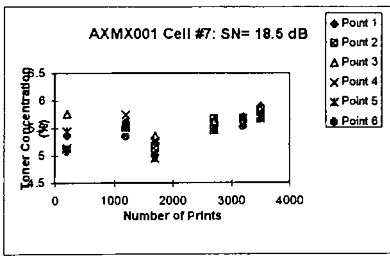

AXMX001 Cell #2: SN= 19.1 dB
Toner Concentration (%)
Number of Prints
Point 1
Point 2
Point 3
Point 4
Point 5
Point 6

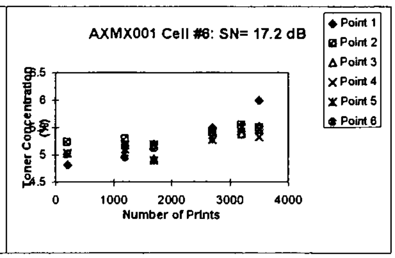

AXMX001 Cell #3: SN= 18.3 dB
Toner Concentration (%)
Number of Prints
Point 1
Point 2
Point 3
Point 4
Point 5
Point 6

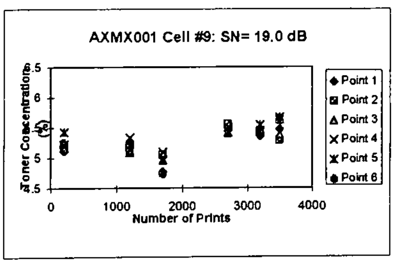

AXMX001 Cell #4: SN= 14.3 dB
Toner Concentration (%)
Number of Prints
Point 1
Point 2
Point 3
Point 4
Point 5
Point 6

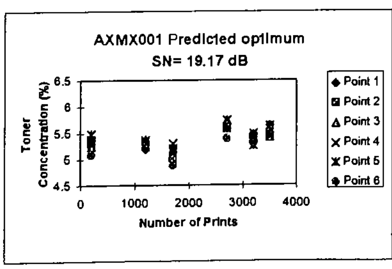

AXMX001 Cell #5: SN= 19.4dB
Toner Concentration (%)
Number of Prints
Point 1
Point 2
Point 3
Point 4
Point 5
Point 6

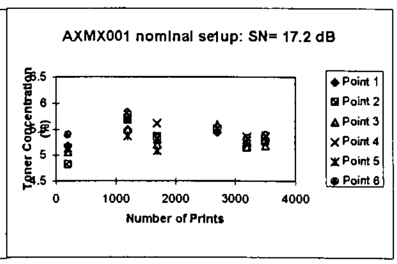

AXMX001 Cell #6: SN= 11.7 dB
Toner Concentration (%)
Number of Prints
Point 1
Point 2
Point 3
Point 4
Point 5
Point 6


AXMX001 Cell #7: SN= 18.5 dB
Toner Concentration (%)
Number of Prints
Point 1
Point 2
Point 3
Point 4
Point 5
Point 6


AXMX001 Cell #8: SN= 17.2 dB
Toner Concentration (%)
Number of Prints
Point 1
Point 2
Point 3
Point 4
Point 5
Point 6


AXMX001 Cell #9: SN= 19.0 dB
Toner Concentration (%)
Number of Prints
Point 1
Point 2
Point 3
Point 4
Point 5
Point 6


AXMX001 Predicted optimum
SN= 19.17 dB
Toner Concentration (%)
Number of Prints
Point 1
Point 2
Point 3
Point 4
Point 5
Point 6


AXMX001 nominal setup: SN= 17.2 dB
Toner Concentration (%)
Number of Prints
Point 1
Point 2
Point 3
Point 4
Point 5
Point 6

APPENDIX C
Taguchi Analysis of Toner Concentration

TCstandard Deviation Analysis
L9 Orthogonal Array

Factors	Response	Analysis	Signals	Noises	Replicates	Target	SNType
4	TCvariance	Static	0	3	2	0	smaller-the-better

Levels	3	3	3	3					
Run	**MixAuger**	**ickupAug**	**xAugerSpe**	**MOR**	**Means**	**StdDev**	**SNRatios**	**Betas**	**AvLoss**
1	**4890 styl**	**0.3**	**400**	**0.2**	0.1469059	0.0701407	15.90		0 03
2	**4890 styl**	**0.5**	**300**	**0.25**	0.10335884	0.0425147	19 14		0.01
3	**4890 styl**	**0.7**	**200**	**0.3**	0.1097984	0.0581709	18.33		0.01
4	**helical**	**0.3**	**300**	**0.3**	0.17941054	0.0787852	14.31		0.04
5	**helical**	**0.5**	**200**	**0.2**	0.10145224	0.0358314	19.45		0 01
6	**helical**	**0.7**	**400**	**0.25**	0.17882941	0.2048804	11.75		0 07
7	**4890 styl**	**0.3**	**200**	**0.25**	0.13344254	0.0738839	18.51		0 02
8	**4890 styl**	**0.5**	**400**	**0.3**	0.12735889	0.0574548	17.22		0.02
9	**4890 styl**	**0.7**	**300**	**0.2**	0.10588878	0.041144	18.99		0.01

S/N Ratio Factor Effects

	Level1	Level2	Level3	Levl4	Level5	Optimum S/N Ratio	Levels	
MixAuger	17.791827	15.16757	17.5734			17.79182707	1	[redacted]
PickupAug	15.573861	18.603087	16.35585			18.60308665	2	
MixAugerS	14.956474	17.478846	18.09747			18.09747273	3	
MOR	18.114493	15.799392	16.61891			18.11449318	1	

Mean Factor Effects

	Level1	Level2	Level3	Level4	Level5	Means	
MixAuger	0.1200204	0.1531641	0.122223			0.120020377	[redacted]
PickupAug	0.153253	0.1107226	0.131432			0.110722591	
MixAugerS	0.1509647	0.1295454	0.114898			0.114897726	
MOR	0.1180756	0.1384763	0.138856			0.118075639	

Signal To Noise Ratio

Overall Mean	16.84426
Optimum	22.07409
Total SNRatio SS	2605.846

Response Mean

Overall Mean	0.131803
Optimum	0.068309
Total Mean SS	0.007597

Beta Factor Effects

	Beta Totlal Sum of Squares				
	Level1	Level2	Level3	Level4	Level5
MixAuger					
PickupAuger					
MixAugerSpeed					
MOR					

Loss Factor Effects

	Level1	Level2	Level3	Level4	Level5
MixAuger	0.0175183	0.038446	0.017973		
PickupAuge	0.0283696	0.0141702	0.031397		
MixAugerS	0.0371802	0.0206356	0.016121		
MOR	0.0165502	0.0338021	0.023585		

ANOVA Table

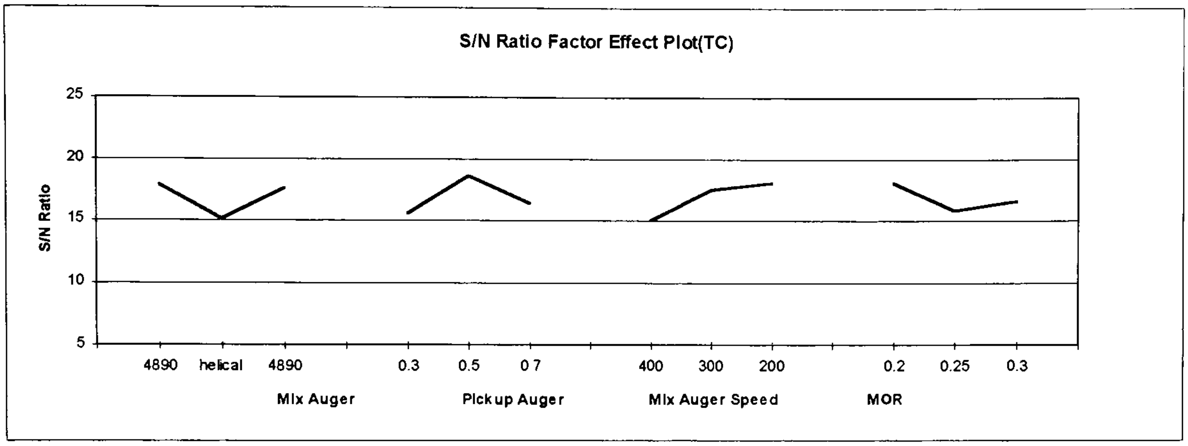
	Correction Factor			0.156347	
Means	DOF	SS	MSV	F Ratio	% Contrib
MixAuger	2	0.0020607	0.00103		27.13%
PickupAuge	2	0.0027139	0.001357		35.72%
MixAugerSpe	2	0.0019742	0.000987		25.99%
MOR	2	0.0008481	0.000424		11.16%
Error	0	-1.39E-16			

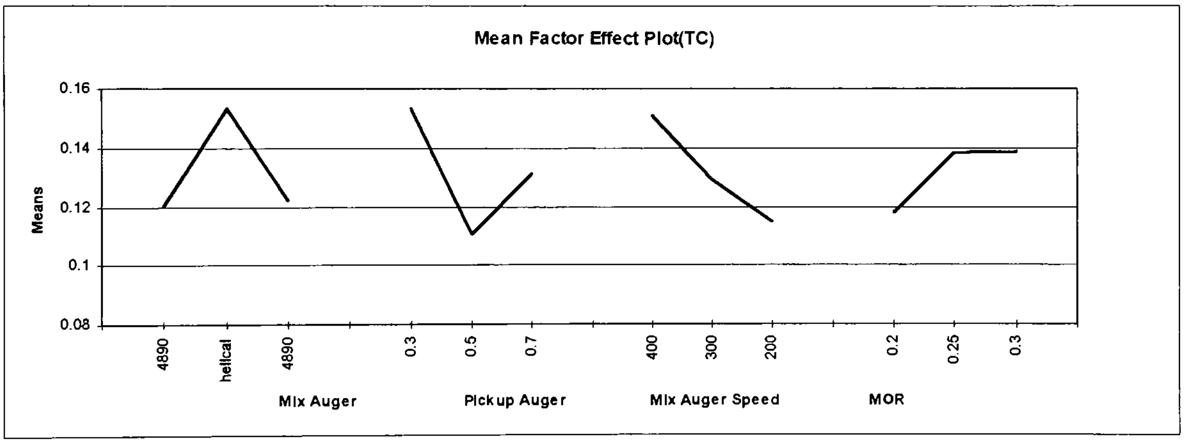
ANOVA Table

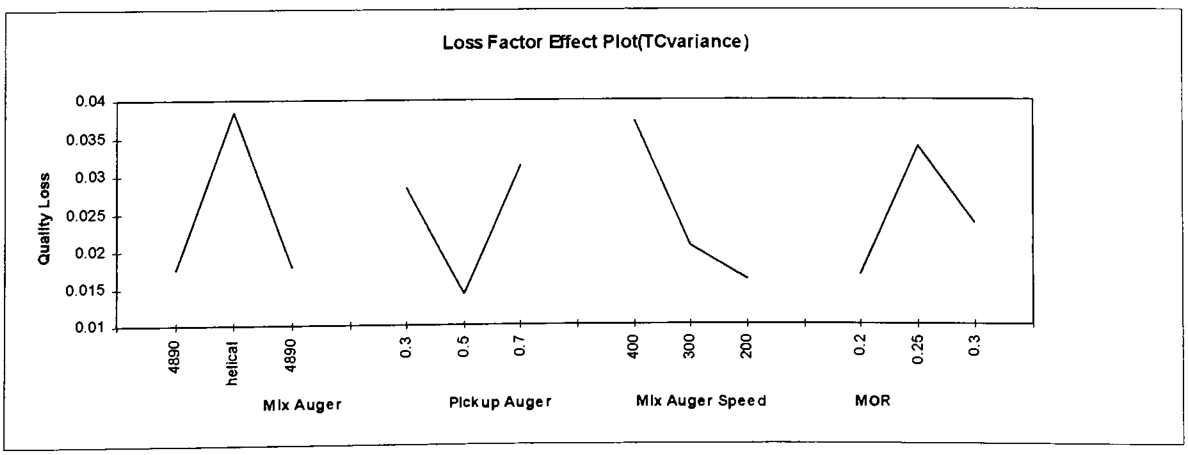
	Correction Factor			2553.563	
SNRatios	DOF	SS	MSV	F Ratio	% Contrib
MixAuger	2	12.722443	6.361222		24.26%
PickupAuge	2	14.837802	7.418901		28.30%
MixAugerSpe	2	16.610929	8.305464		31.68%
MOR	2	8.2680738	4.134037		15.77%
Error	0	4.547E-13			

Factor SS Effects

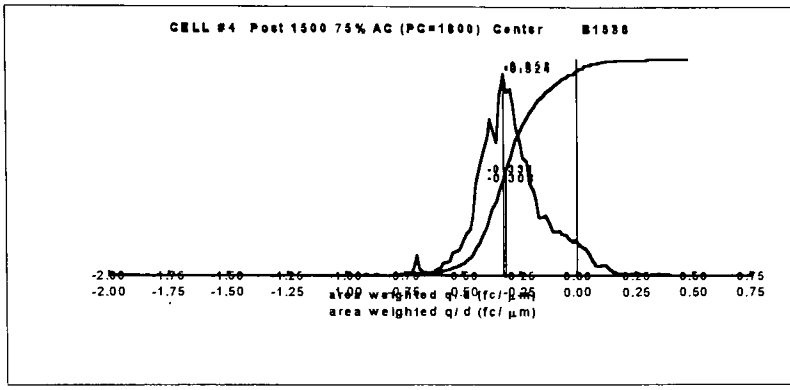
	Level1	Level2	Level3	Level4	Level5
MixAuger	0.0432147	0.0703777	0.044816		
PickupAuge	0.0704594	0.0367785	0.051823		
MixAugerSpe	0.068371	0.050346	0.039604		
MOR	0.0418256	0.057527	0.057843		


S/N Ratio Factor Effect Plot(TC)
S/N Ratio
25
20
15
10
5
4890
helical
4890
0.3
0.5
0 7
400
300
200
0.2
0.25
0.3
Mix Auger
Pickup Auger
Mix Auger Speed
MOR

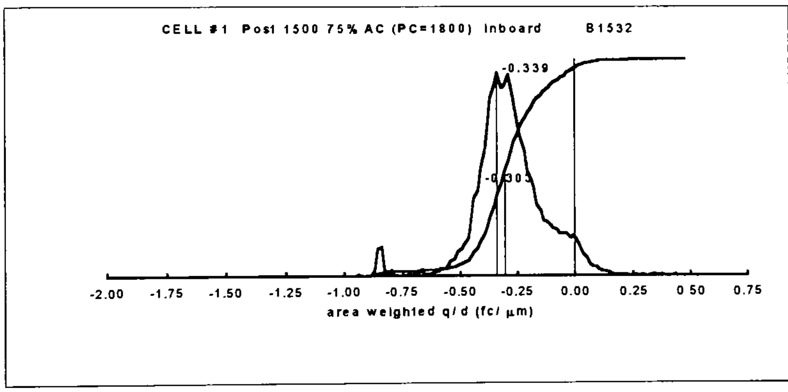

Mean Factor Effect Plot(TC)
Means
0.16
0.14
0.12
0.1
0.08
4890
helical
4890
0.3
0.5
0.7
400
300
200
0.2
0.25
0.3
Mix Auger
Pickup Auger
Mix Auger Speed
MOR


Loss Factor Effect Plot(TCvariance)
Quality Loss
0.04
0.035
0.03
0.025
0.02
0.015
0.01
4890
helical
4890
0.3
0.5
0.7
400
300
200
0.2
0.25
0.3
Mix Auger
Pickup Auger
Mix Auger Speed
MOR

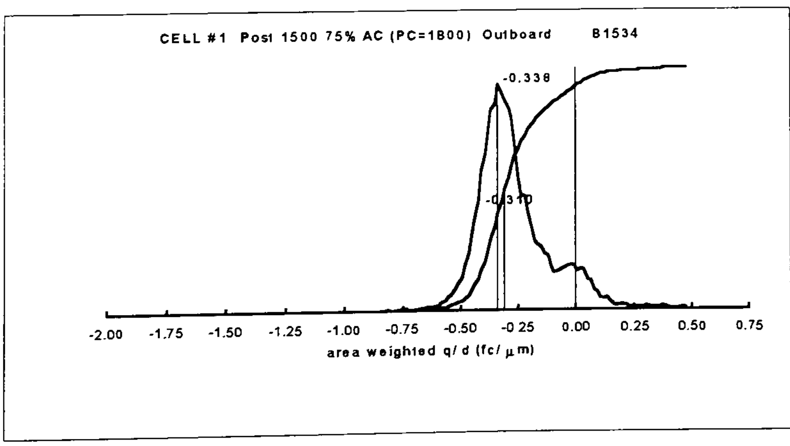
APPENDIX D
Summarized Charge Spectography Data



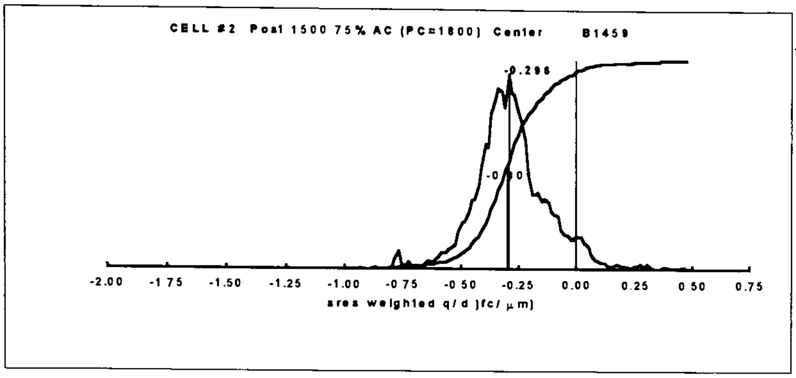
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter ID	###### B1533
							q/d <18	-0.422
1	0	0	0	0	0	0	q/d <50	-0.308
2	3.483	0.888	2.298	-0.18	0.255	-1.589	q/d <84	-0.142
3	10.809	2.908	7.34	-0.131	0.202	-1.544	pk	-0.324
4	18.074	3.778	11.771	-0.141	0.164	-1.165	rsd 7	-0.489
5	12.883	1.828	7.087	-0.177	0.161	-0.809	clc	0.1485
6	12.712	1.293	5.8	-0.218	0.167	-0.78	cws	0.0848
7	8.13	0.888	3.18	-0.258	0.171	-0.664	ws 7	0.0378
8	8.389	0.848	2.888	-0.277	0.17	-0.812	d avg(2)	8.9
9	7.291	0.437	1.857	-0.297	0.168	-0.568	corr coe	0
10	5.709	0.325	1.291	-0.309	0.169	-0.538	N	13821
11	4.208	0.148	0.802	-0.329	0.161	-0.481		
12	2.517	0.089	0.417	-0.331	0.154	-0.465		
13	1.558	0.057	0.256	-0.331	0.154	-0.464		
14	0.923	0.032	0.127	-0.33	0.138	-0.421		
15	0.588	0.022	0.077	-0.338	0.148	-0.438		
16	0.34	0.012	0.037	-0.337	0.158	-0.47		
17	0.218	0.007	0.027	-0.338	0.122	-0.38		
18	0.129	0.002	0.007	-0.348	0.138	-0.4		
19	0.07	0.007	0.007	-0.321	0.183	-0.602		
20	0.035	0.005	0.005	-0.302	0.262	-0.868		
21	0.017	0	0	-0.409	0.04	-0.088		
22	0.007	0.002	0.002	-0.148	0.478	-3.213		
23	0.005	0	0	-0.31	0.073	-0.234		
24	0.005	0	0	-0.484	0.045	-0.092		
25	0.002	0	0	-0.852	0	0		
26	0.007	0	0	-0.348	0.102	-0.292		
27	0.002	0	0	-0.853	0	0		
28	0.002	0	0	-0.847	0	0		
	0.9998	AVERAGE VAL		-0.22	0.172	-0.884		



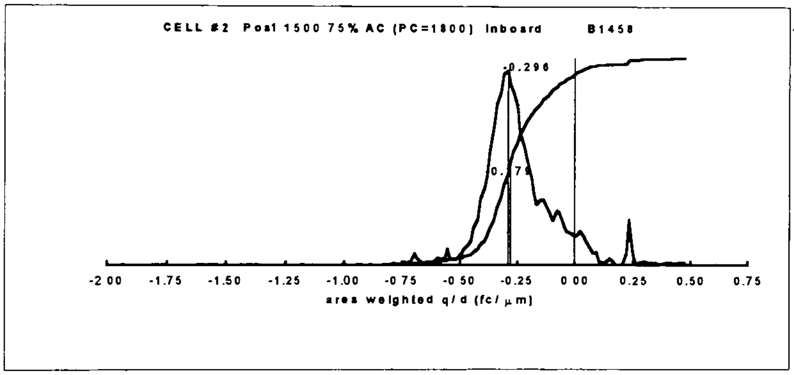
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter ID	###### 81532
							q/d <18	-0.41
1	0	0	0	0	0	0	q/d <50	-0.303
2	8.208	1.545	4.107	-0.151	0.232	-1.535	q/d <84	-0.148
3	17.862	3.722	11.832	-0.138	0.188	-1.227	pk	-0.338
4	18.584	2.244	8.465	-0.18	0.148	-0.818	rsd 7	-0.489
5	11.035	0.784	4.387	-0.22	0.148	-0.662	clc	0.1481
6	11.343	0.548	3.567	-0.248	0.14	-0.565	cws	0.0527
7	8.609	0.255	2.224	-0.272	0.133	-0.489	ws 7	0.029
8	8.018	0.178	1.895	-0.292	0.125	-0.427	d avg(2)	8.89
9	8 609	0.13	1.102	-0.296	0.118	-0.387	corr coe	0
10	4.818	0.101	0.741	-0.311	0.128	-0.418	N	20771
11	2.887	0.029	0.347	-0.32	0.111	-0.348		
12	1.458	0.024	0.173	-0.318	0.115	-0.382		
13	0.883	0	0.072	-0.321	0.083	-0.296		
14	0.424	0.005	0.048	-0.314	0.122	-0.388		
15	0.183	0	0.014	-0.331	0.121	-0.364		
16	0.135	0	0.01	-0.32	0.071	-0.22		
17	0.048	0	0.005	-0.281	0.082	-0.327		
18	0.034	0	0	-0.458	0.208	-0.454		
19	0.01	0	0	-0.314	0.029	-0.089		
	0.9994	AVERAGE VAL		-0.223	0.147	-0 751		



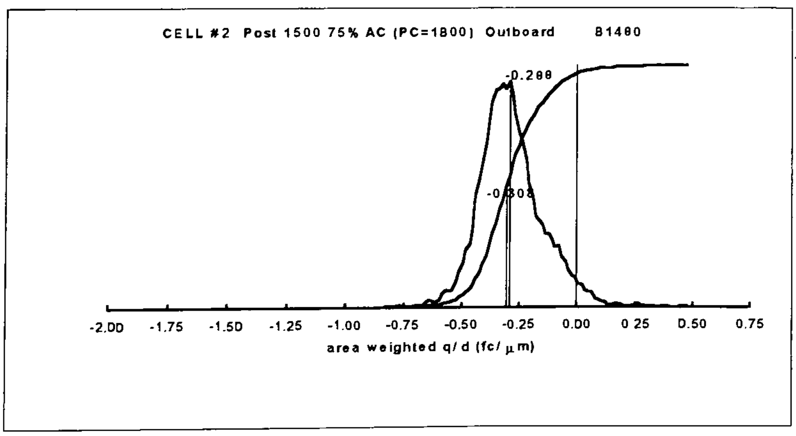
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter ID	###### B1534
							q/d <18	-0.411
1	0	0	0	0	0	0	q/d <50	-0.31
2	4.289	1.427	3.088	-0.107	0.203	-1.901	q/d <84	-0.124
3	13.155	3.897	8.27	-0.101	0.164	-1.818	pk	-0.338
4	18.372	4.888	11.882	-0.138	0.16	-1.153	rsd 7	-0.609
5	12.488	1.744	8.052	-0.189	0.156	-0.828	clc	0.189
6	13.092	0.978	4.13	-0.24	0.148	-0.815	cws	0.1008
7	8.032	0.41	2.273	-0.275	0.14	-0.609	ws 7	0.0454
8	8.514	0.337	1.738	-0.284	0.135	-0.48	d avg(2)	8.84
9	8.818	0.185	1.011	-0.314	0.13	-0.414	corr coe	0
10	5.481	0.172	0.727	-0.313	0.133	-0 424	N	15135
11	2.953	0.066	0.278	-0.327	0.121	-0.37		
12	1.878	0.088	0.178	-0.315	0.156	-0.485		
13	0.965	0.088	0.152	-0.296	0.171	-0.578		
14	0.609	0.02	0.046	-0.327	0.17	-0.52		
15	0.264	0 02	0.048	-0.278	0.158	-0.577		
16	0.158	0.033	0 033	-0.228	0.181	-0.837		
17	0.088	0.013	0.02	-0.221	0.183	-0.738		
18	0.058	0.028	0.028	-0.043	0.364	-8.483		
19	0.013	0	0	-0.424	0.023	-0.053		
20	0.013	0	0	-0.384	0.023	-0 058		
21	0.013	0.007	0.007	-0.338	0.558	-1 858		
	0.9688	AVERAGE VAL		-0.212	0.152	-0.878		



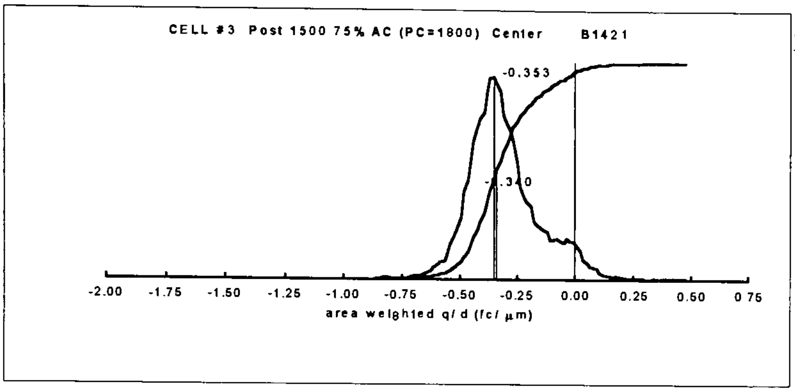
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter ID	###### B1458
							q/d <18	-0.425
1	0	0	0	0	0	0	q/d <50	-0.301
2	3.483	0.988	2.298	-0.18	0.255	-1.588	q/d <84	-0.138
3	10.808	2.908	7.34	-0.131	0.202	-1.544	pk	-0.298
4	18.074	3.778	11 771	-0 141	0.184	-1.185	rsd 7	-0.408
5	12.963	1.828	7.087	-0.177	0.181	-0.906	clc	0.127
8	12.712	1.283	5.8	-0.218	0.167	-0.78	cws	0.0528
7	8.13	0 888	3.18	-0.258	0 171	-0.884	ws 7	0.0115
8	8.388	0.848	2.988	-0.277	0.17	-0.612	d avg(2)	5.48
8	7.281	0.437	1.857	-0.287	0.188	-0.569	corr coe	0
10	5.708	0.325	1.281	-0.308	0.188	-0.538	N	6048
11	4.208	0.148	0.802	-0.328	0.181	-0.481		
12	2.517	0.088	0.417	-0.331	0.154	-0.485		
13	1.558	0.057	0.258	-0.331	0.154	-0.464		
14	0 823	0.032	0 127	-0.33	0.138	-0.421		
15	0.588	0.022	0.077	-0.338	0.148	-0.438		
18	0.34	0.012	0.037	-0.337	0.158	-0.47		
17	0.218	0.007	0.027	-0.338	0.122	-0.36		
18	0.128	0.002	0.007	-0.348	0.138	-0.4		
18	0.07	0.007	0.007	-0.321	0.183	-0.602		
20	0.035	0.005	0.005	-0.302	0.282	-0.888		
21	0.017	0	0	-0.408	0.04	-0.098		
22	0.007	0.002	0.002	-0.148	0.478	-3.213		
23	0.005	0	0	-0.31	0.073	-0.234		
24	0.005	0	0	-0.484	0.045	-0.082		
25	0.002	0	0	-0.852	0	0		
28	0.007	0	0	-0.348	0.102	-0.292		
27	0.002	0	0	-0.853	0	0		
28	0.002	0	0	-0.847	0	0		
	0.9988	AVERAGE VAL		-0.22	0.172	-0.884		



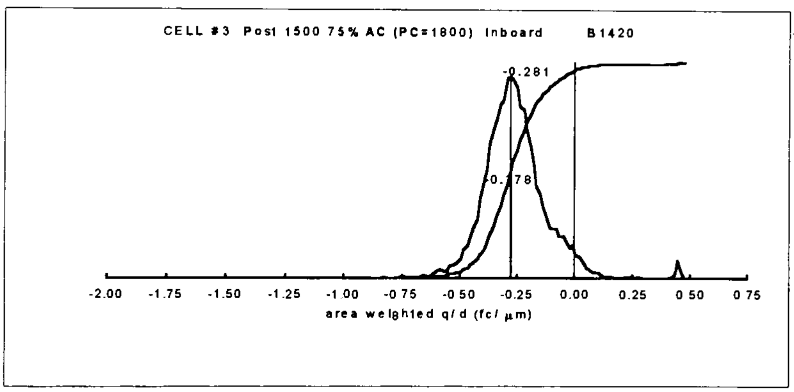
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter ID	###### B1458
							q/d <18	-0.378
1	0	0	0	0	0	0	q/d <50	-0.278
2	8.404	1.295	3.873	-0.181	0.283	-1.564	q/d <84	-0.098
3	18.833	3.377	10.788	-0.142	0.204	-1.44	pk	-0.298
4	25.475	2.73	13.172	-0.18	0.148	-0.823	rsd 7	-0.438
5	18 707	1.055	8.122	-0.224	0.133	-0.585	clc	0.1561
8	15.355	0.833	4.025	-0.253	0.128	-0.507	cws	0.0607
7	8.712	0.253	1.421	-0.287	0.128	-0.438	ws 7	0.029
8	5.855	0.098	0.605	-0.31	0.118	-0.378	d avg(2)	5.7
8	2.604	0.042	0.31	-0.302	0.117	-0.388	corr coe	0
10	0.943	0.014	0.127	-0.318	0.123	-0.385	N	7108
11	0.563	0.084	0.127	-0.245	0.224	-0.818		
12	0.183	0	0.042	-0.308	0.127	-0.411		
13	0.188	0.028	0.042	-0.218	0.224	-1.041		
14	0.084	0	0.014	-0.295	0.113	-0.385		
15	0.029	0.014	0.014	-0.108	0.385	-3 458		
18	0.014	0.014	0.014	0.038	0	0		
17	0.014	0.014	0.014	0.081	0	0		
18	0.014	0	0	-0.281	0	0		
18	0.014	0	0	-0.552	0	0		
	0.9997	AVERAGE VAL		-0.214	0.156	-0.813		



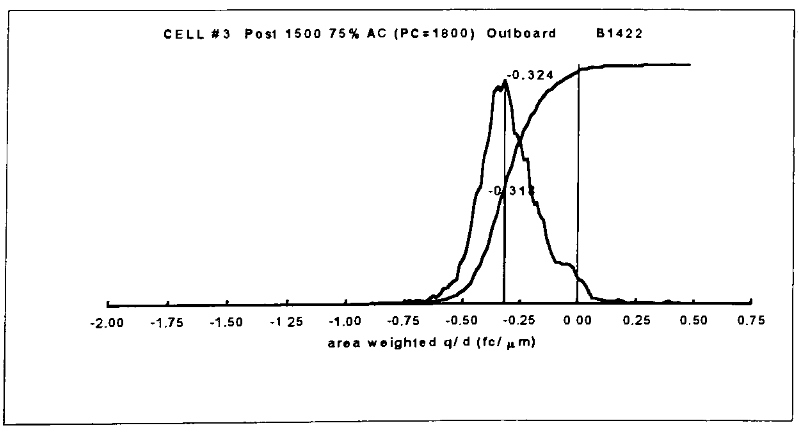
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter ID	###### B1460
							q/d <18	-0.418
1	0	0	0	0	0	0	q/d <50	-0.308
2	3.807	0.838	2.556	-0.158	0.229	-1.45	q/d <84	-0.157
3	12.017	2.207	8.043	-0.147	0.182	-1.241	pk	-0.298
4	18.518	1.851	10 44	-0.175	0.143	-0.818	rsd 7	-0.475
5	12.827	0.744	5 17	-0.222	0.137	-0.618	clc	0.1408
8	12.835	0.523	4 051	-0.252	0.138	-0.548	cws	0.0462
7	8.215	0.282	2.035	-0.284	0.135	-0.475	ws 7	0.0284
8	8.811	0 148	1.888	-0.303	0.123	-0 405	d avg(2)	7.08
8	7.543	0.137	1.255	-0.308	0.132	-0.427	corr coe	0
10	5.544	0.083	0.728	-0.322	0.128	-0.38	N	18810
11	3.828	0.048	0.464	-0.318	0.128	-0.401		
12	2.1	0 038	0.232	-0.323	0.121	-0.374		
13	0.848	0.018	0.137	-0.322	0.14	-0.438		
14	0.583	0	0.085	-0.332	0.108	-0.328		
15	0.308	0.012	0.048	-0.281	0.145	-0.514		
18	0.18	0.018	0.042	-0.313	0.203	-0.648		
17	0.048	0	0	-0.355	0.103	-0.28		
18	0.048	0	0.008	-0.368	0.183	-0.488		
18	0.024	0.005	0.012	-0.12	0.288	-2.251		
	0.8888	AVERAGE VAL		-0.238	0.144	-0.875		



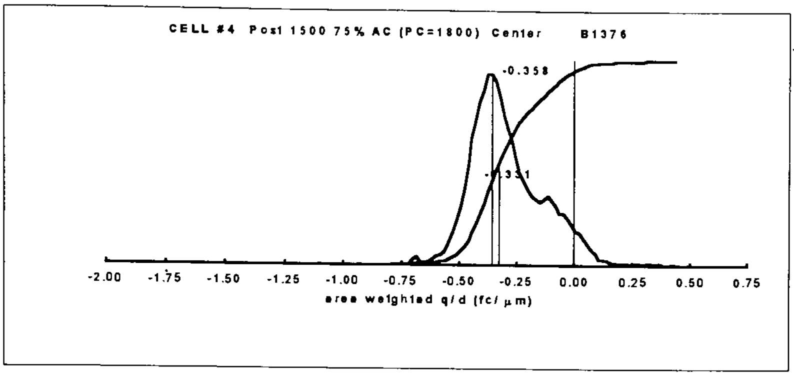
Diamet	Relative Freque	% Wron Sign	% Low Charge	Avereg Q/D	ST0 of Q/D	Relat. ST0	meter I0	###### 81421
							q/d <18	-0.453
1	0	0	0	0	0	0	q/d <50	-0.34
2	3.483	0.888	2.288	-0.18	0.255	-1.588	q/d <84	-0.185
3	10 808	2.808	7.34	-0.131	0.202	-1.544	pk	-0.353
4	18.074	3.778	11.771	-0.141	0.164	-1.185	rsd 7	-0.405
5	12.883	1.828	7.087	-0.177	0.181	-0.808	clc	0.1388
8	12.712	1.283	5.8	-0.218	0.167	-0.78	cws	0.0527
7	8.13	0.888	3.18	-0.258	0.171	-0.864	ws 7	0.0195
8	8.388	0 648	2 888	-0.277	0.17	-0.812	d avg(2)	8.34
9	7.281	0 437	1.857	-0.287	0 188	-0.588	corr coe	0
10	5.708	0.325	1.281	-0 308	0 188	-0.538	N	16445
11	4.208	0 148	0.802	-0.328	0 181	-0.481		
12	2 517	0 088	0.417	-0.331	0.154	-0.485		
13	1.558	0.057	0.258	-0.331	0.154	-0.464		
14	0.823	0.032	0.127	-0.33	0.138	-0.421		
15	0 588	0 022	0.077	-0.338	0.148	-0.438		
18	0.34	0.012	0.037	-0.337	0.158	-0.47		
17	0 218	0.007	0.027	-0.338	0.122	-0.38		
18	0.128	0.002	0.007	-0.348	0 138	-0.4		
18	0 07	0 007	0.007	-0.321	0.183	-0.802		
20	0.035	0.005	0.005	-0.302	0.282	-0.888		
21	0.017	0	0	-0.408	0.04	-0.098		
22	0.007	0.002	0.002	-0.148	0.478	-3.213		
23	0 005	0	0	-0.31	0.073	-0.234		
24	0 005	0	0	-0.464	0.045	-0.082		
25	0.002	0	0	-0.852	0	0		
28	0.007	0	0	-0.348	0.102	-0.292		
27	0.002	0	0	-0.853	0	0		
29	0.002	0	0	-0.647	0	0		
	0.8888	AVERAGE VAL		-0.22	0.172	-0.864		



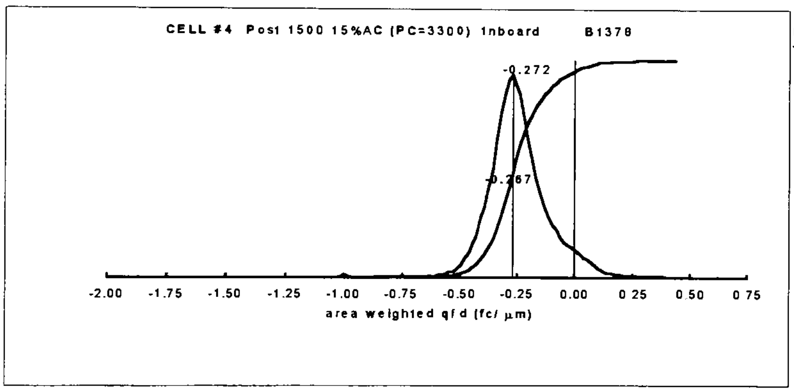
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	ST0 of Q/D	Relat. ST0	meter I0	###### 81420
							6>	-0.364
1	0	0	0	0	0	0	8>	-0.278
2	4.544	0.788	2 731	-0 175	0.22	-1.258	4>	-0.148
3	14 873	1.782	8 708	-0.17	0.187	-0.878	pk	-0.281
4	20.171	1.835	10.113	-0.18	0.142	-0.751	rsd 7	-0.473
5	13.087	0.538	4.785	-0.232	0.13	-0.58	clc	13.08%
8	12 472	0 364	3.528	-0.281	0.135	-0.518	cws	3.91%
7	8.831	0.215	2.014	-0.275	0.13	-0.473	ws 7	2.41%
8	8.488	0.151	1.782	-0.289	0.117	-0.406	d avg(2)	8.78
8	5.808	0.085	1.125	-0.284	0.111	-0.381	rr coeff	0
10	4.808	0.085	0 838	-0.287	0 111	-0.388	N	13952
11	2.774	0.022	0.809	-0.292	0.113	-0.4		
12	1 455	0.022	0.401	-0.283	0.113	-0 428		
13	0.896	0.014	0.215	-0.254	0.112	-0.438		
14	0.444	0	0.05	-0.282	0.088	-0.308		
15	0.229	0 007	0.043	-0.258	0.087	-0.375		
18	0.143	0	0.043	-0.283	0.124	-0.439		
17	0.043	0.007	0.007	-0.188	0.22	-1.11		
18	0.029	0	0	-0.34	0.088	-0.185		
18	0.007	0	0	-0.573	0	0		
20	0.007	0	0.007	-0.188	0	0		
	1	AVERAGE VAL		-0.233	0 138	-0.838		



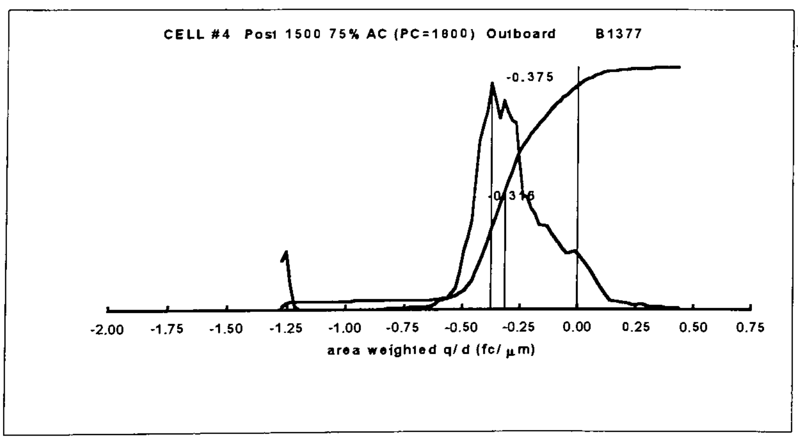
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	ST0 of Q/D	Relat. ST0	meter I0	###### 81422
							q/d <18	-0.427
1	0	0	0	0	0	0	q/d <50	-0.318
2	5.517	0.71	2.644	-0.215	0.248	-1.154	q/d <84	-0.174
3	15.802	1.77	8.718	-0.187	0 187	-1.001	pk	-0.324
4	20.888	1.42	10.58	-0.188	0.148	-0.741	rsd 7	-0.378
5	12.814	0.525	4.448	-0.248	0.137	-0.553	clc	0.1148
8	12.528	0.288	3.128	-0.278	0.132	-0.474	cws	0.0318
7	8 893	0.082	1.389	-0.305	0 115	-0.378	ws 7	0.0082
8	8 471	0.124	1.278	-0.318	0.125	-0.388	d avg(2)	8.65
8	8.247	0.082	0.7	-0.327	0.118	-0.381	corr coe	0
10	3.838	0.031	0 422	-0.337	0.117	-0.345	N	8718
11	2.264	0.051	0.208	-0 334	0.123	-0.398		
12	1.564	0.01	0.237	-0.33	0.125	-0.378		
13	0 782	0	0 082	-0.342	0.118	-0.338		
14	0.247	0	0.031	-0 355	0.128	-0.362		
15	0 175	0.01	0.021	-0.321	0.178	-0.558		
18	0.021	0.01	0.01	-0.034	0.564	-17.88		
17	0.021	0	0	-0.408	0.018	-0 045		
18	0.01	0	0	-0.435	0	0		
19	0.01	0	0	-0.372	0	0		
	0.8889	AVERAGE VAL		-0.254	0.147	-0.832		



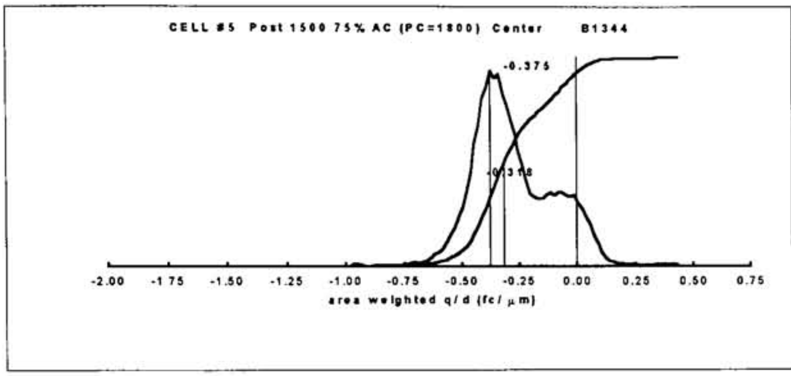
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter	######
							ID	81378
							q/d <18	-0.445
1	0	0	0	0	0	0	q/d <50	-0.331
2	3.483	0.888	2.288	-0.18	0.255	-1.588	q/d <84	-0.124
3	10.808	2.908	7.34	-0.131	0.202	-1.544	pk	-0.358
4	18.074	3.778	11.771	-0.141	0.184	-1.185	rsd 7	-0.485
5	12.883	1.828	7.087	-0.177	0.181	-0.806	clc	0.1825
6	12.712	1.283	5.8	-0.218	0.187	-0.78	cws	0.088
7	8.13	0.688	3.18	-0.258	0.171	-0.884	ws 7	0.0312
8	8.388	0.848	2.888	-0.277	0.17	-0.812	d avg(2)	8.55
9	7.281	0.437	1.857	-0.287	0.188	-0.588	corr coe	0
10	5.708	0.325	1.281	-0.308	0.188	-0.538	N	36515
11	4.208	0.148	0.902	-0.328	0.181	-0.481		
12	2.517	0.088	0.417	-0.331	0.154	-0.465		
13	1.558	0.057	0.258	-0.331	0.154	-0.464		
14	0.823	0.032	0.127	-0.33	0.138	-0.421		
15	0.588	0.022	0.077	-0.338	0.148	-0.438		
16	0.34	0.012	0.037	-0.337	0.158	-0.47		
17	0.218	0.007	0.027	-0.338	0.122	-0.36		
18	0.128	0.002	0.007	-0.348	0.138	-0.4		
19	0.07	0.007	0.007	-0.321	0.183	-0.602		
20	0.035	0.005	0.005	-0.302	0.282	-0.888		
21	0.017	0	0	-0.408	0.04	-0.099		
22	0.007	0.002	0.002	-0.148	0.478	-3.213		
23	0.005	0	0	-0.31	0.073	-0.234		
24	0.005	0	0	-0.464	0.045	-0.092		
25	0.002	0	0	-0.852	0	0		
26	0.007	0	0	-0.348	0.102	-0.292		
27	0.002	0	0	-0.853	0	0		
28	0.002	0	0	-0.847	0	0		
	0.8999	AVERAGE VAL		-0.22	0.172	-0.884		



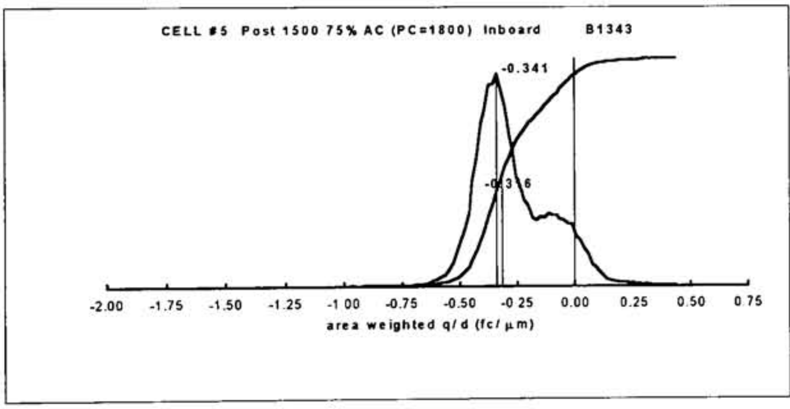
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter	######
							ID	81378
							q/d <18	-0.365
1	0	0	0	0	0	0	q/d <50	-0.267
2	2.478	0.887	1.874	-0.082	0.215	-2.622	q/d <84	-0.134
3	9.548	2.834	7.881	-0.084	0.182	-1.837	pk	-0.272
4	20.875	4.58	15.508	-0.111	0.14	-1.258	rsd 7	-0.536
5	14.334	1.787	8.783	-0.157	0.131	-0.838	clc	0.2188
6	13.453	0.878	8.352	-0.201	0.127	-0.831	cws	0.0818
7	8.36	0.354	3.289	-0.236	0.128	-0.536	ws 7	0.0378
8	8.018	0.187	2.438	-0.258	0.118	-0.455	d avg(2)	7.02
9	8.528	0.092	1.315	-0.278	0.112	-0.402	corr coe	0
10	4.847	0.073	0.883	-0.286	0.118	-0.413	N	54457
11	3.278	0.082	0.474	-0.287	0.117	-0.408		
12	2.071	0.044	0.275	-0.265	0.114	-0.398		
13	1.382	0.028	0.183	-0.289	0.105	-0.363		
14	0.888	0.011	0.099	-0.294	0.101	-0.343		
15	0.593	0.009	0.048	-0.295	0.087	-0.34		
16	0.371	0	0.028	-0.301	0.08	-0.288		
17	0.228	0	0.015	-0.287	0.061	-0.205		
18	0.158	0	0.007	-0.265	0.057	-0.201		
19	0.123	0	0.002	-0.287	0.05	-0.174		
20	0.084	0	0	-0.301	0.048	-0.154		
21	0.058	0	0	-0.288	0.048	-0.188		
22	0.031	0	0.002	-0.312	0.099	-0.313		
23	0.024	0	0.002	-0.302	0.055	-0.182		
24	0.013	0	0	-0.286	0.045	-0.158		
25	0.011	0	0	-0.281	0.028	-0.084		
	0.9998	AVERAGE VAL		-0.188	0.131	-0.88		



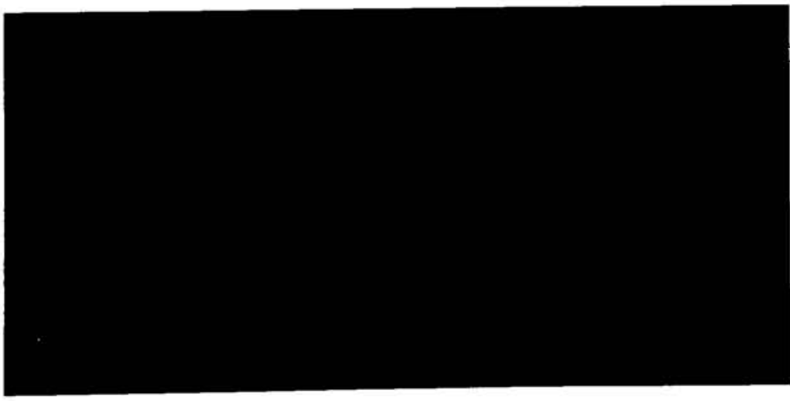
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter	######
							ID	81377
							q/d <18	-0.438
1	0	0	0	0	0	0	q/d <50	-0.316
2	3.845	1.376	2.858	-0.122	0.307	-2.513	q/d <84	-0.106
3	12.442	3.902	8.588	-0.086	0.18	-1.887	pk	-0.375
4	24.284	5.343	18.298	-0.132	0.157	-1.188	rsd 7	-0.518
5	14.414	1.85	7.254	-0.188	0.158	-0.827	clc	0.2282
6	12.305	0.887	4.258	-0.246	0.154	-0.828	cws	0.1082
7	8.176	0.286	2.032	-0.287	0.148	-0.518	ws 7	0.0362
8	7.888	0.243	1.577	-0.308	0.138	-0.453	d avg(2)	8.81
9	8.101	0.171	0.878	-0.32	0.138	-0.433	corr coe	0
10	4.282	0.128	0.512	-0.334	0.14	-0.418	N	28372
11	2.858	0.133	0.41	-0.318	0.154	-0.487		
12	1.414	0.084	0.171	-0.336	0.163	-0.485		
13	0.804	0.048	0.125	-0.318	0.164	-0.518		
14	0.428	0.034	0.085	-0.308	0.201	-0.853		
15	0.294	0.018	0.048	-0.308	0.188	-0.544		
16	0.155	0.011	0.023	-0.393	0.301	-0.788		
17	0.088	0.004	0.004	-0.308	0.381	-0.771		
18	0.03	0.009	0.011	-0.288	0.464	-1.728		
19	0.015	0	0	-0.369	0.051	-0.137		
20	0.034	0.004	0.008	-0.858	0.812	-0.714		
21	0.004	0	0	-1.283	0	0		
	0.9991	AVERAGE VAL		-0.208	0.183	-0.883		



Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter	######
							ID	B1343
							q/d <16	-0.425
1	0	0	0	0	0	0	q/d <50	-0.316
2	3.483	0.988	2.286	-0.16	0.255	-1.588	q/d <84	-0.09
3	10.609	2.909	7.34	-0.131	0.202	-1.544	pk	-0.341
4	18.074	3.776	11.771	-0.141	0 164	-1.165	rsd 7	-0.677
5	12.863	1.926	7.067	-0.177	0.161	-0.906	clc	0.2369
6	12 712	1.293	5.6	-0.219	0.167	-0.76	cws	0.0995
7	9.13	0.698	3.18	-0.258	0.171	-0.684	ws 7	0.0772
8	9.398	0.648	2.889	-0.277	0.17	-0.612	d avg(2)	7.51
9	7.281	0.437	1.857	-0.297	0.169	-0.569	corr coe	0
10	5 709	0.325	1.291	-0 309	0.166	-0.538	N	50181
11	4.208	0.149	0.802	-0.328	0 161	-0.491		
12	2.517	0 089	0.417	-0.331	0.154	-0 465		
13	1.559	0.057	0 258	-0.331	0.154	-0.464		
14	0.923	0 032	0.127	-0.33	0.139	-0.421		
15	0.588	0.022	0.077	-0.339	0.148	-0 438		
16	0.34	0.012	0 037	-0.337	0.158	-0.47		
17	0.216	0.007	0.027	-0.338	0.122	-0.36		
18	0.129	0.002	0.007	-0.348	0.139	-0.4		
19	0.07	0.007	0.007	-0.321	0.193	-0.602		
20	0.035	0.005	0 005	-0.302	0.262	-0.868		
21	0.017	0	0	-0.409	0.04	-0.099		
22	0 007	0.002	0.002	-0.148	0.476	-3.213		
23	0.005	0	0	-0.31	0.073	-0.234		
24	0.005	0	0	-0.484	0.045	-0.092		
25	0 002	0	0	-0.952	0	0		
26	0.007	0	0	-0.348	0.102	-0.292		
27	0.002	0	0	-0.953	0	0		
28	0.002	0	0	-0.947	0	0		
	0 99993	AVERAGE VALUES		-0.22	0 172	-0 884		



Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter	######
							ID	B1343
								-0.425
1	0	0	0	0	0	0		-0.316
2	3.326	1.04	2.224	-0.158	0.28	-1.794		-0.090
3	10.667	3.041	7 491	-0.13	0.218	-1.682	pk	-0.341
4	16.604	3 671	11.231	-0.137	0.177	-1.291	rsd 7	-0.677
5	11.909	1 722	6.7	-0.18	0.172	-0 955	clc	23.69%
6	12.295	1.212	5.341	-0.224	0.17	-0.76	cws	9.95%
7	8.942	0 69	3.332	-0.245	0.166	-0.677	ws 7	7.72%
8	9.535	0.544	2.77	-0.274	0.162	-0.59	d avg(2)	7.51
9	7.608	0 43	2.065	-0.282	0.163	-0.576	rr coeff	0
10	6.192	0.283	1.383	-0.299	0.153	-0.514	N	50181
11	4.398	0.213	0.951	-0.301	0.158	-0.525		
12	3.155	0.151	0.612	-0.308	0.153	-0.5		
13	1.907	0.072	0.343	-0.307	0.145	-0 471		
14	1.261	0.022	0.191	-0.318	0.139	-0 436		
15	0.817	0.008	0.084	-0.329	0.113	-0.345		
16	0 508	0.016	0.074	-0.312	0.145	-0 466		
17	0.313	0.006	0.022	-0.329	0.116	-0.354		
18	0 171	0.008	0.014	-0 323	0 129	-0.401		
19	0.145	0.004	0 008	-0.333	0.119	-0.358		
20	0.102	0.004	0 012	-0.315	0 147	-0.467		
21	0 05	0	0.002	-0.353	0.065	-0.184		
22	0.038	0	0	-0.372	0.082	-0.222		
23	0.016	0	0	-0.353	0.019	-0.054		
24	0.018	0	0	-0.356	0.036	-0 101		
25	0.01	0	0	-0.349	0.015	-0.044		
	0.9999	AVERAGE VAL		-0.219	0 174	-0.914		



Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter	######
							ID	
							q/d <16>	
No 1	Data	Data	Portboard	Outboard			q/d <50>	
2							q/d <84>	
3							pk	
4							rsd 7	
5							clc	
6							cws	
7							ws 7	
8							d avg(2)	
9							corr coeff	
10							N	
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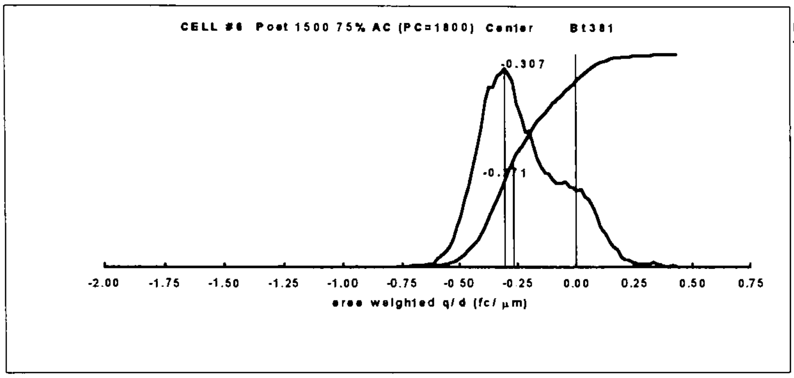
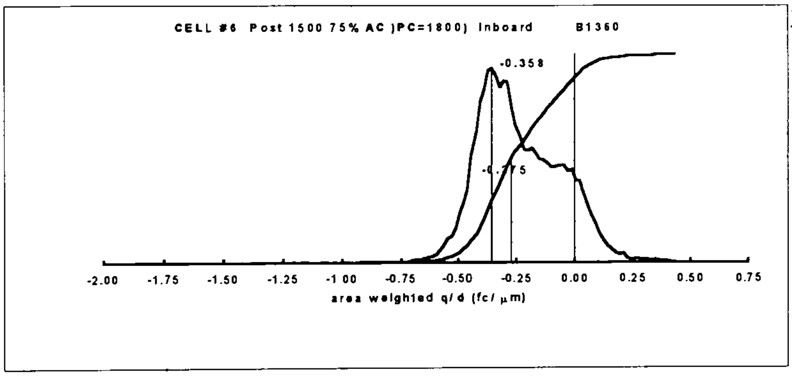
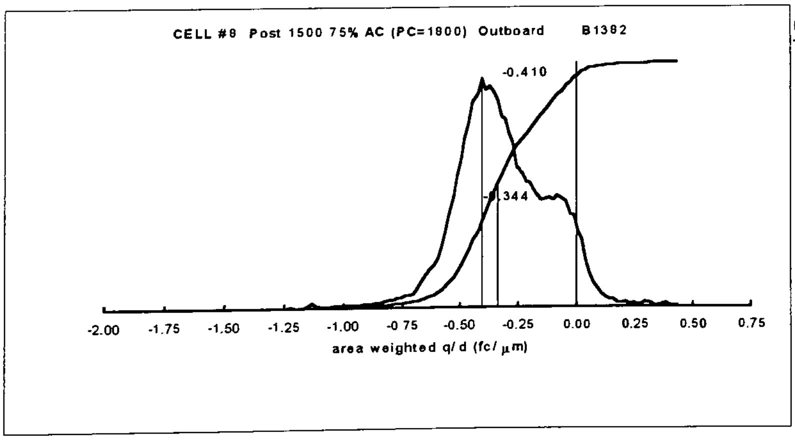


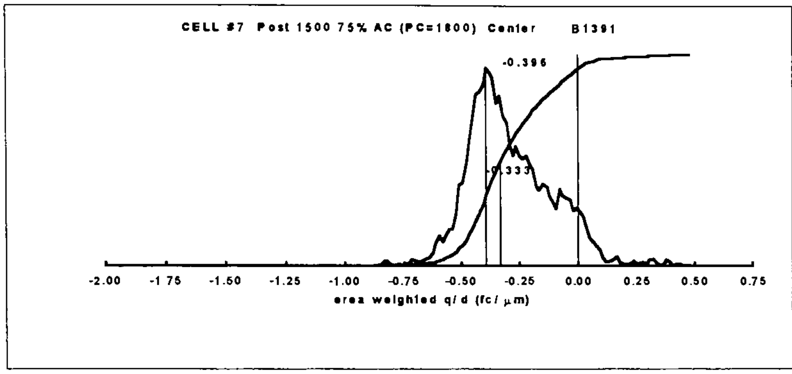
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter	######
							ID	81381
							q/d <18	-0.411
1	0	0	0	0	0	0	q/d <50	-0.271
2	3 483	0.888	2.298	-0 18	0.255	-1.568	q/d <84	-0.035
3	10.608	2.909	7.34	-0.131	0.202	-1.544	pk	-0.307
4	18.074	3.778	11.771	-0 141	0.184	-1.185	rsd 7	-0.723
5	12.993	1.928	7.087	-0.177	0.181	-0.909	clc	0.2945
6	12.712	1.233	5.8	-0.218	0.187	-0.78	cws	0.1701
7	8.13	0.898	3.18	-0.258	0.171	-0.664	ws 7	0.1018
8	8.388	0.648	2.988	-0.277	0.17	-0.812	d avg(2)	8.81
9	7.281	0.437	1 857	-0.287	0.188	-0.569	corr coe	0
10	5.709	0.325	1.281	-0.309	0.188	-0.538	N	45778
11	4.208	0.148	0.602	-0.328	0.181	-0.481		
12	2 517	0.089	0.417	-0 331	0.154	-0.465		
13	1 558	0.057	0.256	-0.331	0 154	-0.464		
14	0 923	0.032	0.127	-0 33	0.139	-0.421		
15	0.598	0.022	0.077	-0.338	0.148	-0.438		
16	0 34	0.012	0.037	-0.337	0.158	-0.47		
17	0.218	0.007	0.027	-0.338	0.122	-0.36		
18	0.128	0.002	0.007	-0.348	0.138	-0.4		
19	0.07	0.007	0.007	-0.321	0.193	-0.602		
20	0 035	0.005	0.005	-0.302	0.262	-0.868		
21	0.017	0	0	-0.408	0.04	-0.099		
22	0.007	0.002	0.002	-0 148	0.478	-3.213		
23	0.005	0	0	-0.31	0.073	-0.234		
24	0.005	0	0	-0.484	0.045	-0.092		
25	0.002	0	0	-0.952	0	0		
26	0.007	0	0	-0.348	0.102	-0.292		
27	0.002	0	0	-0.853	0	0		
28	0.002	0	0	-0.847	0	0		
	0.9999	AVERAGE VAL		-0.22	0.172	-0 664		



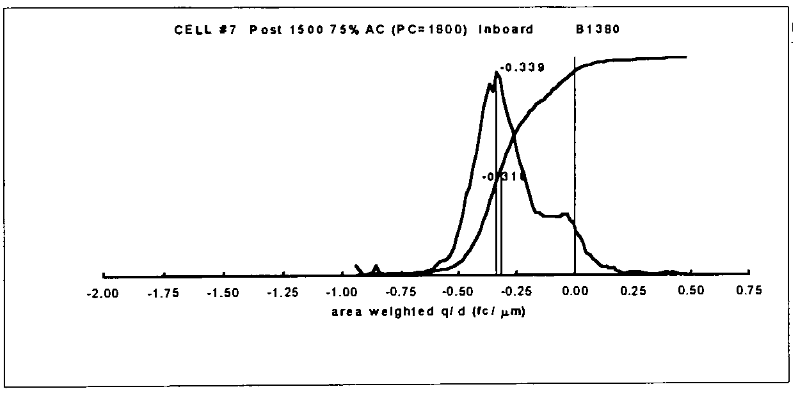
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter	######
							ID	81360
							q/d <18	-0.417
1	0	0	0	0	0	0	q/d <50	-0.275
2	8.028	2.342	4.641	-0.088	0.228	-2.577	q/d <84	-0.042
3	18.874	8.68	15.287	-0.084	0.178	-2.118	pk	-0.358
4	23.148	8.891	18.81	-0.105	0.164	-1.558	rsd 7	-0.656
5	12.298	2.188	7.034	-0.165	0.168	-1.018	clc	0.2806
6	11.078	1.294	5.078	-0.211	0 168	-0.788	cws	0.1359
7	7.43	0.58	2.838	-0.248	0.181	-0.656	ws 7	0.0754
8	7.258	0.337	2.164	-0.272	0.157	-0.577	d avg(2)	8.44
9	4.889	0.189	1.187	-0.294	0.154	-0.524	corr coe	0
10	3.342	0.11	0.885	-0.311	0.153	-0.493	N	38112
11	1.871	0.078	0.371	-0.317	0.158	-0.502		
12	1.332	0.028	0.24	-0.318	0.15	-0.47		
13	0.683	0.038	0.138	-0.309	0.168	-0.544		
14	0.404	0.02	0.084	-0.32	0 177	-0.554		
15	0.187	0.023	0.049	-0.288	0.223	-0.778		
16	0.123	0.003	0.02	-0.314	0.101	-0.32		
17	0.058	0.013	0.023	-0.253	0.283	-1.038		
18	0.038	0.005	0.005	-0.288	0.236	-0.781		
19	0.018	0.008	0.008	-0.125	0.342	-2.74		
20	0.013	0.005	0.008	-0.092	0.307	-3.343		
21	0.005	0.003	0.003	-0.045	0.373	-8.205		
22	0.003	0	0	-0.238	0	0		
23	0.005	0.003	0.003	-0.473	0.647	-2.003		
24	0.003	0.003	0.003	0.207	0	0		
	0.8889	AVERAGE VAL		-0.188	0.17	-1.305		



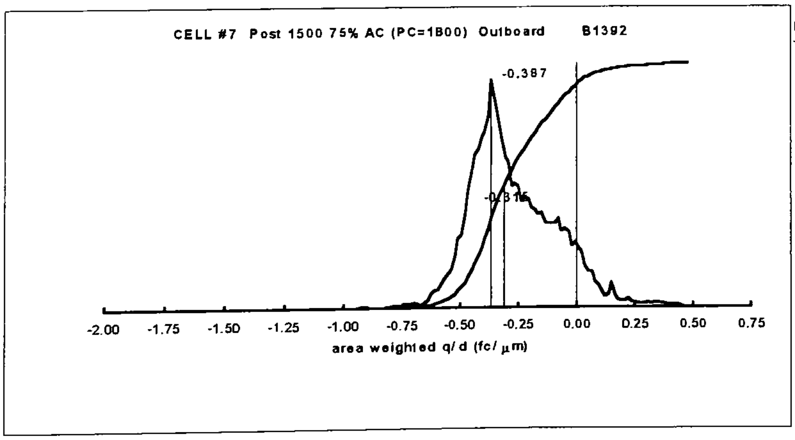
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter	######
							ID	81362
							q/d <18	-0.505
1	0	0	0	0	0	0	q/d <50	-0.344
2	4.552	0.996	3.373	-0.128	0.205	-1.562	q/d <84	-0.104
3	18.534	3 001	11.751	-0 131	0.181	-1.232	pk	-0.41
4	22.482	2.867	13.933	-0 181	0.155	-0.962	rsd 7	-0.582
5	13.824	1.174	8 701	-0.208	0.164	-0.785	clc	0.2087
6	11.827	0.933	4.344	-0.257	0.174	-0.877	cws	0.0662
7	7.852	0.282	2.144	-0.304	0.177	-0.562	ws 7	0.0388
8	7 458	0.188	1.542	-0.343	0.178	-0.52	d avg(2)	8.88
9	5 178	0.127	0.804	-0.378	0.181	-0.463	corr coe	0
10	4.008	0.081	0.527	-0.385	0.178	-0.451	N	83855
11	2.7	0.056	0.287	-0 408	0.174	-0 428		
12	1.681	0.058	0.202	-0.387	0.181	-0.46		
13	0.882	0.03	0.097	-0 402	0.187	-0.415		
14	0.582	0.031	0.067	-0.388	0.188	-0.513		
15	0.385	0.026	0 045	-0.387	0.182	-0.497		
16	0.207	0.011	0.027	-0.373	0 181	-0.512		
17	0.127	0.007	0.017	-0.371	0.187	-0.503		
18	0 088	0.008	0.01	-0.363	0.179	-0.485		
19	0.048	0.005	0.008	-0.331	0.242	-0.732		
20	0.022	0.004	0.008	-0.281	0.284	-1.01		
21	0 009	0.001	0.002	-0.318	0.208	-0.854		
22	0.011	0.003	0 003	-0.28	0.373	-1.323		
23	0.01	0	0.002	-0.335	0.198	-0.584		
24	0.002	0	0	-0.515	0 181	-0.313		
25	0.002	0.001	0.002	-0.008	0.027	-2.607		
	0.9999	AVERAGE VAL		-0.233	0.168	-0.836		



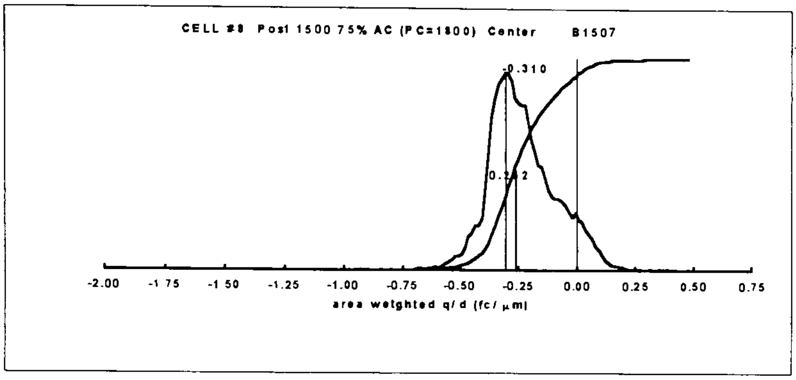
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag O/D	STD of O/D	Relat. STD	meter ID	######
								B1381
							q/d <18	-0.484
1	0	0	0	0	0	0	q/d <50	-0.333
2	3.483	0.888	2.288	-0.18	0.255	-1.588	q/d <84	-0.097
3	10.809	2.908	7.34	-0.131	0.202	-1.544	pk	-0.388
4	18 074	3.778	11.771	-0.141	0.164	-1.185	rsd 7	-0.554
5	12 883	1.828	7.087	-0.177	0.181	-0.809	clc	0.2013
8	12.712	1.283	5.8	-0.218	0.187	-0.78	cws	0.0755
7	8 13	0.888	3.18	-0.258	0.171	-0.664	ws 7	0.0484
8	8.388	0.848	2.888	-0.277	0.17	-0.812	d avg(2)	8.78
8	7.281	0.437	1.857	-0.287	0.188	-0.588	corr coe	0
10	5.709	0.325	1.281	-0.308	0.188	-0.536	N	12605
11	4.209	0.148	0.902	-0.328	0.181	-0.481		
12	2.517	0.098	0.417	-0.331	0.154	-0.465		
13	1.558	0.057	0.258	-0.331	0.154	-0.464		
14	0.923	0.032	0.127	-0.33	0.138	-0.421		
15	0.588	0 022	0.077	-0.338	0.148	-0.436		
18	0.34	0.012	0.037	-0.337	0.158	-0.47		
17	0.218	0.007	0.027	-0.338	0.122	-0.36		
18	0.128	0.002	0.007	-0.348	0.138	-0.4		
18	0.07	0.007	0.007	-0.321	0.183	-0.602		
20	0.035	0.005	0.005	-0.302	0.282	-0.868		
21	0.017	0	0	-0.409	0.04	-0.099		
22	0.007	0.002	0.002	-0.146	0.478	-3.213		
23	0.005	0	0	-0.31	0.073	-0.234		
24	0.005	0	0	-0.464	0.045	-0.092		
25	0.002	0	0	-0.952	0	0		
28	0.007	0	0	-0.348	0.102	-0.292		
27	0.002	0	0	-0.853	0	0		
28	0.002	0	0	-0.847	0	0		
	0.8888	AVERAGE VAL		-0.22	0.172	-0.664		



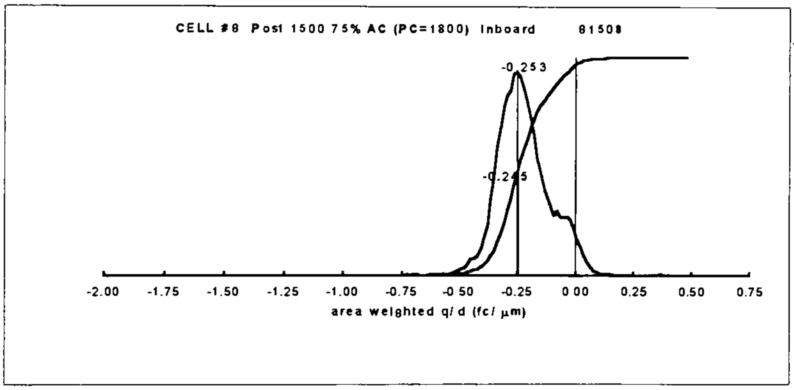
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag O/D	STD of O/D	Relat. STD	meter ID	######
								B1390
							q/d <18	-0.432
1	0	0	0	0	0	0	q/d <50	-0.318
2	4.224	1.188	3.104	-0.121	0.223	-1.836	q/d <84	-0.105
3	15.378	3.518	11.01	-0.118	0.18	-1.348	pk	-0.338
4	22.099	3.718	13.084	-0.153	0.148	-0.874	rsd 7	-0.527
5	13.142	1.285	5.77	-0.206	0.153	-0.741	clc	0.2053
8	12.282	0.705	4.278	-0.242	0.152	-0.628	cws	0.078
7	8.354	0.295	2.132	-0.278	0.147	-0.527	ws 7	0.0341
8	8.228	0.217	1.709	-0.303	0.143	-0.473	d avg(2)	8.88
8	5.858	0.072	0.848	-0.325	0.136	-0.417	corr coe	0
10	4.378	0.084	0.466	-0.341	0.131	-0.385	N	27876
11	2.847	0.118	0.358	-0.328	0.153	-0 463		
12	1.565	0.04	0.137	-0.344	0.138	-0 402		
13	0.784	0.033	0.078	-0.348	0.15	-0.432		
14	0.488	0.054	0.112	-0.268	0.202	-0.75		
15	0.264	0.004	0.022	-0.338	0.115	-0.338		
18	0 118	0.036	0.04	-0.174	0.309	-1.778		
17	0 078	0.022	0.025	-0.175	0.287	-1.885		
18	0.025	0.004	0.007	-0.222	0.178	-0.785		
18	0.018	0.004	0.004	-0.288	0.291	-1.014		
20	0.018	0	0	-0.72	0.274	-0.381		
21	0.011	0	0	-0.336	0.042	-0.125		
	0 9888	AVERAGE VAL		-0.218	0.153	-0.83		



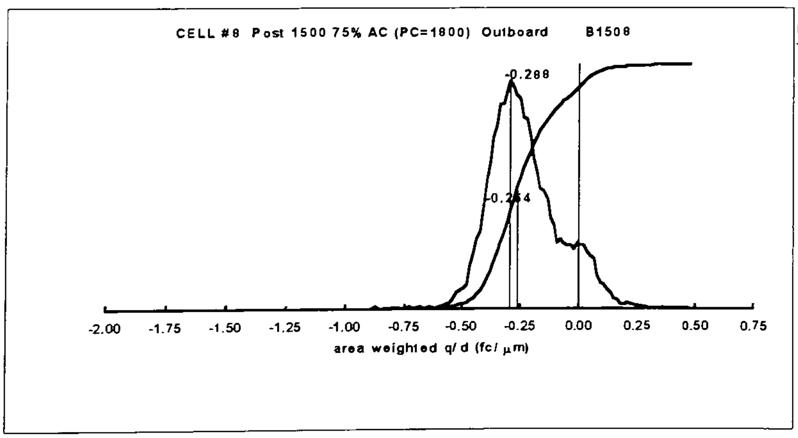
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag O/D	STD of O/D	Relat. STD	meter ID	######
								B1382
							q/d <18	-0.451
1	0	0	0	0	0	0	q/d <50	-0.315
2	5.664	1.87	4.108	-0.116	0.208	-1.774	q/d <84	-0.078
3	17.631	4.588	12.271	-0.123	0.178	-1.448	pk	-0.387
4	21.338	3.857	12.88	-0.158	0.185	-1.044	rsd 7	-0.588
5	12.488	1.537	8.045	-0.21	0.172	-0.823	clc	0.2086
8	11.732	0.827	4.631	-0.248	0.188	-0.878	cws	0.0881
7	8.323	0.347	2.524	-0.282	0.168	-0.589	ws 7	0 0417
8	8.152	0.277	1.793	-0.312	0.154	-0.484	d avg(2)	8.58
8	5.41	0.155	0.887	-0.328	0.153	-0.468	corr coe	0
10	3.638	0.081	0.587	-0.342	0.148	-0.435	N	18743
11	2.385	0.084	0.32	-0.343	0.18	-0.488		
12	1.238	0.085	0.24	-0.322	0.188	-0.578		
13	0.822	0.075	0.181	-0.308	0.224	-0.731		
14	0.378	0.053	0.081	-0.278	0.206	-0.742		
15	0.218	0.053	0.075	-0.21	0.287	-1.385		
18	0.091	0.005	0.021	-0.334	0.188	-0.584		
17	0.037	0.021	0.027	-0.097	0.321	-4.795		
18	0.037	0.005	0.018	-0.188	0.278	-1.495		
18	0.011	0.011	0 011	0.178	0.238	1.33		
20	0.011	0.005	0.005	0.032	0.43	13.485		
21	0.005	0	0	-0.362	0	0		
	0.9999	AVERAGE VAL		-0.213	0.17	-0.828		



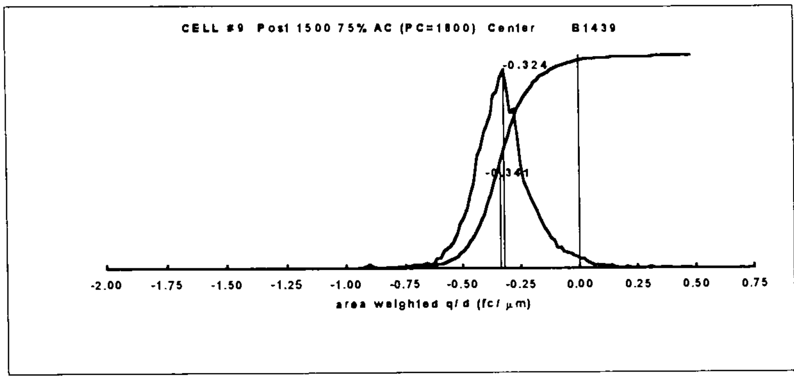
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter ID	###### 81507
							q/d <18	-0.371
1	0	0	0	0	0	0	q/d <50	-0.262
2	3.483	0.888	2.296	-0.18	0.255	-1.588	q/d <84	-0.085
3	10.609	2.909	7.34	-0.131	0.202	-1.544	pk	-0.31
4	18.074	3.776	11.771	-0.141	0.164	-1.165	rsd 7	-0.583
5	12.883	1.928	7 067	-0.177	0.161	-0.906	clc	0.2321
8	12.712	1.293	5.8	-0.218	0.167	-0.78	cws	0.1063
7	8 13	0 888	3.18	-0.258	0.171	-0.664	ws 7	0.0561
8	8.388	0 648	2.888	-0.277	0.17	-0.812	d avg(2)	8.88
8	7.281	0 437	1.857	-0.297	0.188	-0.588	corr coe	0
10	5.708	0 325	1.291	-0.309	0 188	-0.538	N	28451
11	4.208	0.148	0.802	-0.328	0.161	-0.481		
12	2.517	0 088	0.417	-0.331	0.154	-0.465		
13	1.559	0.057	0.258	-0.331	0.154	-0.464		
14	0.923	0.032	0.127	-0.33	0.138	-0.421		
15	0.588	0.022	0 077	-0.338	0.148	-0.438		
16	0.34	0.012	0.037	-0.337	0.158	-0.47		
17	0.218	0.007	0.027	-0.338	0.122	-0.36		
18	0.128	0.002	0.007	-0.348	0.138	-0.4		
18	0.07	0 007	0.007	-0.321	0.193	-0.602		
20	0.035	0.005	0.005	-0.302	0.262	-0.868		
21	0.017	0	0	-0.409	0.04	-0.088		
22	0.007	0.002	0.002	-0.148	0.478	-3.213		
23	0.005	0	0	-0.31	0.073	-0.234		
24	0.005	0	0	-0.464	0.045	-0.092		
25	0.002	0	0	-0.852	0	0		
28	0 007	0	0	-0.348	0.102	-0.292		
27	0.002	0	0	-0.853	0	0		
28	0.002	0	0	-0.947	0	0		
	0.8999	AVERAGE VAL		-0.22	0.172	-0.664		



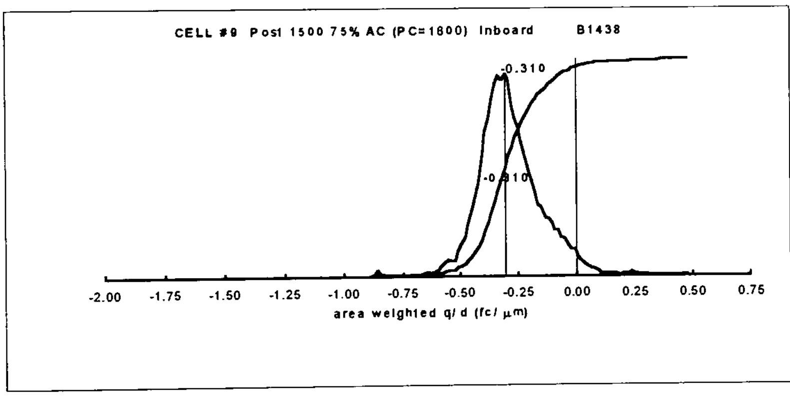
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter ID	###### 81506
							q/d <18	-0.336
1	0	0	0	0	0	0	q/d <50	-0.245
2	5.453	1.009	3.885	-0.128	0.175	-1.366	q/d <84	-0.114
3	17.753	2.878	12.751	-0.128	0 141	-1.094	pk	-0.253
4	21.877	2.318	13.748	-0.153	0 125	-0.815	rsd 7	-0.446
5	12.875	0.877	8.508	-0.188	0.12	-0.638	clc	0.1788
8	12.063	0.44	5.018	-0.215	0.118	-0.555	cws	0.0469
7	7.88	0 158	2.589	-0.237	0.108	-0.446	ws 7	0.0188
8	7.85	0.08	2.245	-0.245	0.104	-0.424	d avg(2)	8.54
8	5.081	0.045	1.291	-0.255	0.1	-0.364	corr coe	0
10	3.868	0.034	0.908	-0.252	0.088	-0.38	N	17732
11	2.218	0.017	0.541	-0.256	0.067	-0.38		
12	1.348	0.009	0.378	-0.244	0.091	-0.372		
13	0.671	0.009	0.158	-0.251	0.088	-0.341		
14	0 423	0	0.085	-0.258	0.088	-0.331		
15	0.242	0	0.078	-0.257	0.095	-0.372		
18	0.113	0	0.011	-0.253	0.062	-0.244		
17	0.038	0	0.017	-0.224	0.088	-0.38		
18	0 034	0	0.011	-0.256	0.058	-0.229		
	0.8899	AVERAGE VAL		-0.187	0.122	-0.718		



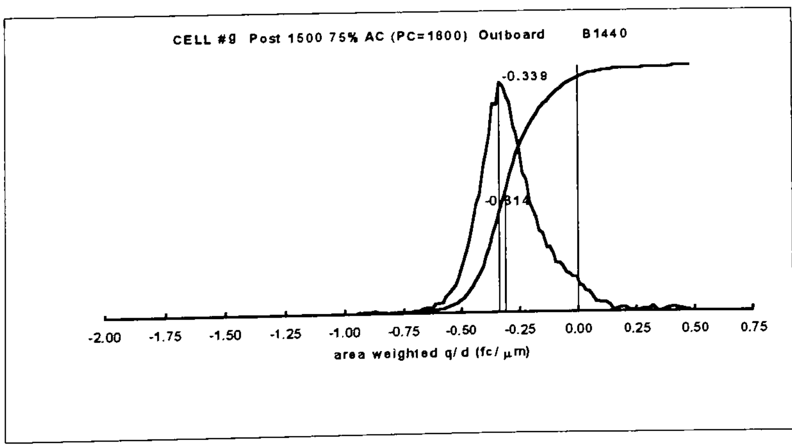
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter ID	###### 81506
							q/d <18	-0.38
1	0	0	0	0	0	0	q/d <50	-0.264
2	8.288	2.738	5.187	-0.04	0.17	-4.298	q/d <84	-0.077
3	18.258	8.648	14.788	-0.078	0.158	-1.874	pk	-0.298
4	20.082	5.088	13.368	-0.12	0.157	-1.309	rsd 7	-0.818
5	11.467	1.88	8.268	-0.188	0.152	-0.82	clc	0.2214
8	11.508	1.231	4.801	-0.208	0.15	-0.73	cws	0.1158
7	8.247	0.583	3.038	-0.23	0.143	-0.818	ws 7	0.0718
8	7.868	0.374	2.088	-0.263	0.138	-0.518	d avg(2)	8.88
8	6.08	0.231	1.341	-0.278	0.13	-0.487	corr coe	0
10	4 143	0.11	0.863	-0.282	0.125	-0 443	N	18200
11	2.335	0.071	0.473	-0.278	0.122	-0 438		
12	1.445	0.027	0.236	-0.297	0.118	-0.392		
13	0.937	0.08	0.154	-0.278	0.18	-0.853		
14	0.33	0	0.044	-0.3	0 101	-0.338		
15	0.17	0	0.022	-0.298	0.075	-0.251		
18	0 088	0	0.005	-0.288	0.063	-0.277		
17	0.033	0	0.011	-0.272	0.172	-0.634		
18	0.018	0	0	-0.31	0.022	-0.071		
18	0.005	0	0	-0.382	0	0		
20	0.018	0	0.005	-0.247	0.223	-0.908		
21	0.005	0	0	-0.868	0	0		
	1	AVERAGE VAL		-0.187	0.148	-1.263		



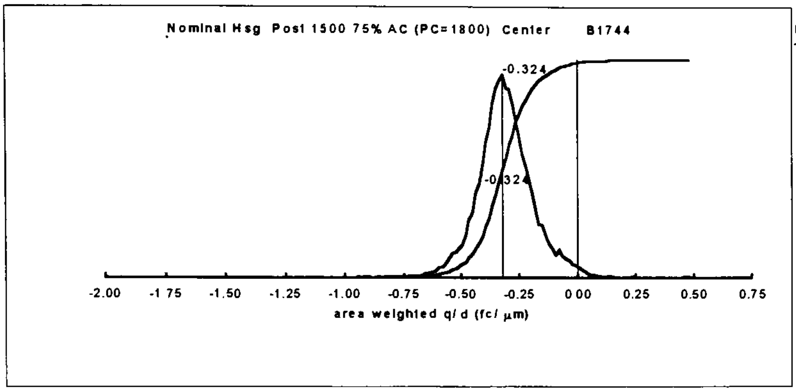
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter ID	###### B1439
							q/d <16	-0.45
1	0	0	0	0	0	0	q/d <50	-0.341
2	3.493	0.999	2.269	-0.16	0.255	-1.599	q/d <84	-0.219
3	10.909	2.909	7.34	-0.131	0.202	-1.544	pk	-0.324
4	19.074	3.776	11.771	-0.141	0.164	-1.165	rsd 7	-0.401
5	12.983	1.926	7.097	-0.177	0.161	-0.909	clc	0.0769
6	12.712	1.293	5.9	-0.219	0.167	-0.79	cws	0.0259
7	9 13	0.699	3.19	-0.258	0.171	-0.664	ws 7	0.0155
8	9.396	0.646	2.699	-0.277	0.17	-0.612	d avg(2)	7.01
9	7.261	0.437	1.957	-0.297	0.169	-0.569	corr coe	0
10	5.709	0.325	1.291	-0.309	0.169	-0.536	N	12046
11	4.206	0.149	0.802	-0.329	0.161	-0.491		
12	2.517	0.099	0 417	-0.331	0.154	-0.465		
13	1.559	0.057	0.258	-0.331	0.154	-0.464		
14	0.923	0.032	0.127	-0.33	0.139	-0.421		
15	0.569	0.022	0.077	-0.339	0.149	-0.438		
16	0.34	0.012	0.037	-0.337	0.159	-0.47		
17	0.216	0.007	0.027	-0.336	0.122	-0.36		
18	0.129	0.002	0.007	-0.348	0.139	-0.4		
19	0.07	0.007	0.007	-0.321	0.193	-0.602		
20	0.035	0.005	0.005	-0.302	0.292	-0.868		
21	0.017	0	0	-0.409	0.04	-0.099		
22	0.007	0.002	0.002	-0 149	0.476	-3.213		
23	0 005	0	0	-0.31	0.073	-0.234		
24	0.005	0	0	-0.464	0.045	-0.092		
25	0.002	0	0	-0.952	0	0		
26	0.007	0	0	-0.348	0.102	-0.292		
27	0.002	0	0	-0.953	0	0		
29	0.002	0	0	-0.947	0	0		
	0.8868	AVERAGE VAL		-0.22	0.172	-0.664		



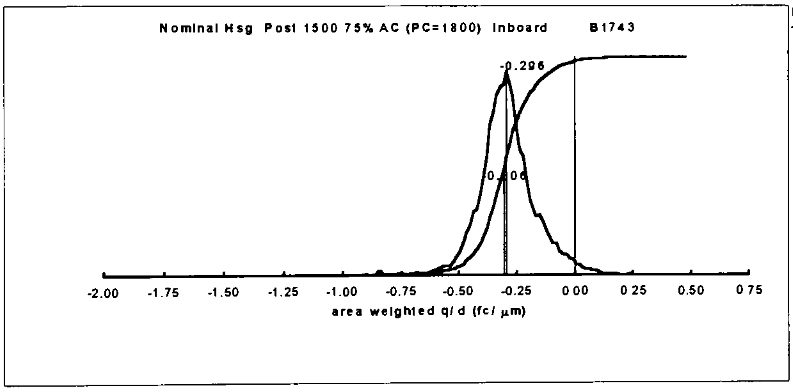
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter ID	###### B1438
							q/d <16	-0.413
1	0	0	0	0	0	0	q/d <50	-0.31
2	4.815	1.412	3.024	-0 119	0.293	-2.438	q/d <84	-0.163
3	13.63	2.243	9.679	-0.144	0.197	-1.369	pk	-0.31
4	22.343	1.699	12.067	-0.163	0.151	-0.923	rsd 7	-0.438
5	13.544	0.691	5.274	-0.23	0.146	-0.632	clc	0.1323
6	12.497	0.297	3.21	-0.271	0.139	-0.513	cws	0.04
7	9.642	0.193	1.564	-0.298	0.13	-0.438	ws 7	0.0223
8	6 112	0.129	1.076	-0.311	0 124	-0.397	d avg(2)	6.7
9	5.691	0.093	0.702	-0.321	0.119	-0.371	corr coe	0
10	4.271	0.079	0.516	-0.318	0.123	-0.39	N	13955
11	2.702	0.05	0.38	-0.312	0.122	-0.369		
12	1.634	0.05	0.251	-0.307	0.136	-0.442		
13	0.931	0	0.079	-0.33	0 102	-0.309		
14	0.516	0.014	0.064	-0.327	0.145	-0.443		
15	0.244	0.007	0.021	-0.303	0.123	-0.407		
16	0.15	0 014	0.036	-0.294	0.161	-0.547		
17	0.057	0	0	-0.311	0.063	-0.201		
19	0.007	0	0	-0.246	0	0		
	0.9999	AVERAGE VAL		-0.234	0.152	-0.769		



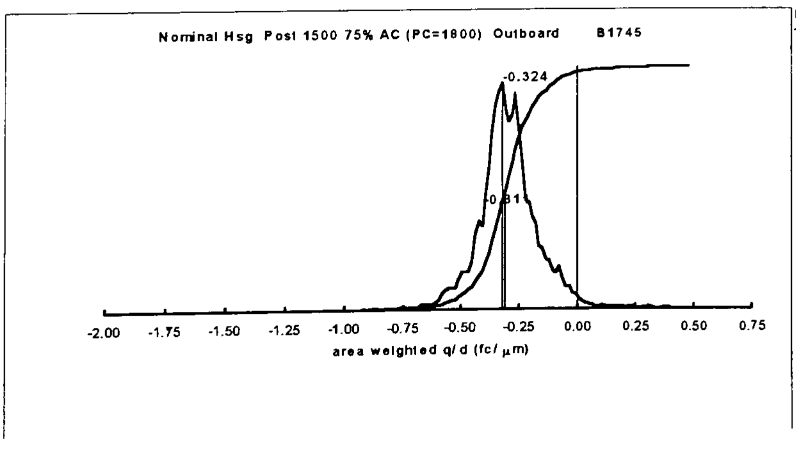
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter ID	###### B1440
							q/d <16	-0.424
1	0	0	0	0	0	0	q/d <50	-0.314
2	3.612	0.945	2.495	-0.135	0.271	-2	q/d <84	-0.156
3	12.113	2.216	8.036	-0.144	0.169	-1.286	pk	-0.339
4	22.967	2.412	12.713	-0.179	0.15	-0.941	rsd 7	-0.437
5	15.464	0.933	6.202	-0.226	0.147	-0.649	clc	0.1491
6	12.749	0.451	3.295	-0.276	0.141	-0.51	cws	0.0525
7	6.555	0.146	1.568	-0.305	0.133	-0 437	ws 7	0.0174
8	6.369	0.16	1.099	-0.32	0.123	-0.365	d avg(2)	6.65
9	5.695	0.101	0.695	-0.327	0.129	-0.391	corr coe	0
10	4.521	0.099	0.467	-0.326	0.132	-0.409	N	16833
11	2.691	0.069	0.321	-0.317	0.137	-0.432		
12	1.604	0.063	0.226	-0.313	0.164	-0.526		
13	0.932	0.03	0.119	-0.323	0.137	-0.424		
14	0.497	0.03	0.077	-0.309	0.167	-0.604		
15	0.166	0.024	0.046	-0.224	0.269	-1.169		
16	0.071	0	0.009	-0.377	0.086	-0.228		
17	0.059	0.012	0.024	-0.203	0.269	-1.31		
18	0.024	0.006	0.006	-0.139	0.304	-2.207		
19	0.006	0	0	-0.249	0	0		
20	0 006	0.006	0.006	0.412	0	0		
	1	AVERAGE VAL		-0.239	0.151	-0.727		



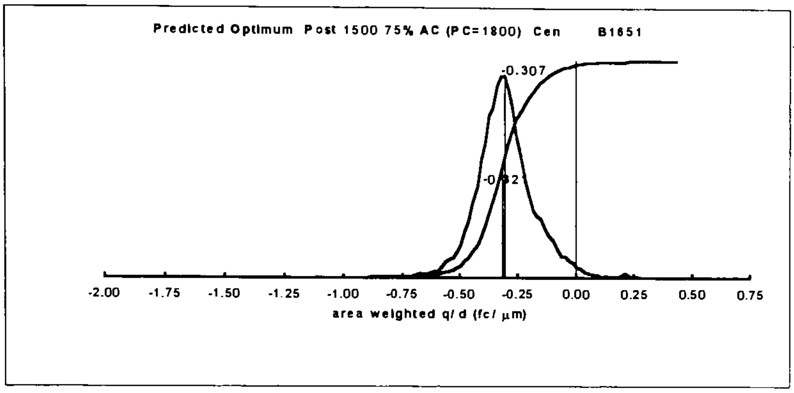
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter ID	###### B1744
							q/d <18	-0.428
1	0	0	0	0	0	0	q/d <50	-0.324
2	3.483	0 888	2.288	-0 18	0.255	-1.588	q/d <84	-0.211
3	10.808	2.808	7.34	-0.131	0.202	-1.544	pk	-0.324
4	18.074	3.778	11.771	-0.141	0.184	-1 185	rsd 7	-0.343
5	12.883	1.828	7.087	-0.177	0.181	-0.808	clc	0.0687
8	12.712	1.283	5.8	-0.218	0 187	-0.78	cws	0.0158
7	8.13	0.888	3.18	-0.258	0 171	-0.684	ws 7	0.0064
8	8.388	0.848	2 888	-0.277	0.17	-0.812	d avg(2)	8.68
8	7.281	0.437	1.857	-0.287	0.188	-0.588	corr coe	0
10	5.708	0.325	1.281	-0.309	0.188	-0.538	N	15963
11	4.209	0.148	0.802	-0.328	0.181	-0.481		
12	2.517	0.089	0 417	-0.331	0.154	-0.485		
13	1.558	0.057	0.258	-0.331	0.154	-0.484		
14	0.923	0.032	0.127	-0.33	0.138	-0.421		
15	0 588	0.022	0.077	-0.338	0.148	-0.438		
18	0.34	0.012	0.037	-0.337	0.158	-0.47		
17	0.218	0.007	0.027	-0.338	0.122	-0.38		
18	0.128	0.002	0.007	-0.348	0.138	-0.4		
18	0.07	0.007	0.007	-0.321	0 183	-0.802		
20	0.035	0.005	0 005	-0.302	0.282	-0.868		
21	0.017	0	0	-0.409	0.04	-0 088		
22	0.007	0.002	0.002	-0.148	0.478	-3.213		
23	0.005	0	0	-0.31	0.073	-0.234		
24	0.005	0	0	-0.464	0.045	-0.092		
25	0.002	0	0	-0.852	0	0		
28	0.007	0	0	-0.348	0.102	-0.292		
27	0.002	0	0	-0.853	0	0		
28	0 002	0	0	-0.847	0	0		
	0.8888	AVERAGE VAL		-0.22	0.172	-0.664		



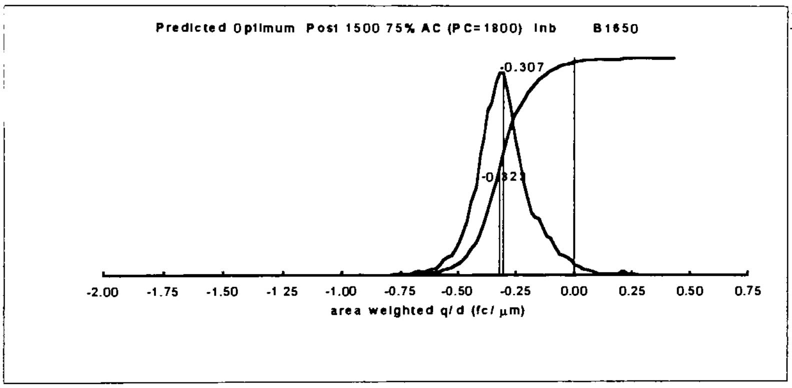
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter ID	###### B1743
							q/d <18	-0.404
1	0	0	0	0	0	0	q/d <50	-0.306
2	4.44	0.618	2.583	-0.188	0 177	-1.043	q/d <84	-0.18
3	10.821	1.504	8.757	-0.18	0.147	-0.823	pk	-0.296
4	17.963	1.355	8.517	-0.162	0.128	-0.7	rsd 7	-0.366
5	13.268	0.538	5.071	-0.222	0.118	-0.535	clc	0.0683
8	12.982	0.194	3.174	-0.262	0.108	-0.418	cws	0.0273
7	8.762	0.072	1.631	-0.29	0.109	-0.388	ws 7	0.0074
8	10.866	0.038	1.382	-0.309	0.103	-0.338	d avg(2)	7.03
8	7.537	0 044	0.758	-0.32	0.108	-0.331	corr coe	0
10	5.474	0.044	0.525	-0.324	0.104	-0.32	N	18084
11	3.39	0.028	0.288	-0.335	0.117	-0.35		
12	1 687	0.028	0.188	-0.322	0.125	-0.38		
13	0.624	0.006	0.088	-0.325	0.112	-0.348		
14	0.492	0	0.044	-0.33	0.083	-0.281		
15	0.138	0	0.017	-0.325	0.112	-0.348		
18	0 088	0	0.011	-0.278	0.082	-0.296		
17	0 068	0	0	-0.374	0.132	-0.354		
18	0 038	0.011	0.011	-0.285	0.287	-1.009		
18	0.011	0	0.008	-0.232	0.07	-0.304		
	0.8888	AVERAGE VAL		-0.247	0.12	-0.537		



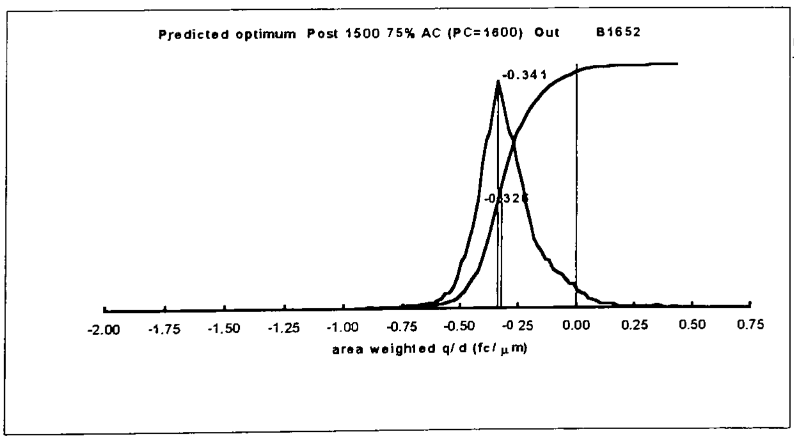
Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STD of Q/D	Relat. STD	meter ID	###### B1745
							q/d <18	-0.41
							q/d <50	-0.311
1	0	0	0	0	0	0	q/d <84	-0.182
2	5.78	0.818	3.271	-0.188	0.237	-1.208	pk	-0.324
3	17.438	1.388	8.884	-0.188	0.188	-0.881	rsd 7	-0.38
4	23.522	0.78	8.742	-0.224	0.131	-0.585	clc	0.0735
5	14.735	0.23	3.422	-0.27	0.122	-0.451	cws	0.018
8	12.878	0.222	2.28	-0.28	0.124	-0 428	ws 7	0.0138
7	7 858	0 106	0.811	-0.317	0.114	-0.36	d avg(2)	8.21
8	7.331	0.1	0.58	-0.331	0.123	-0.371	corr coe	0
8	4 534	0.078	0.402	-0.332	0.123	-0.371	N	13840
10	2.747	0.022	0.285	-0.328	0.122	-0.372		
11	1.521	0.014	0.172	-0.337	0.135	-0.402		
12	0.875	0.014	0.122	-0.307	0.127	-0.412		
13	0.402	0.007	0.057	-0.288	0.128	-0.42		
14	0.256	0.007	0.029	-0.331	0.107	-0.322		
15	0 128	0.007	0.028	-0.271	0.124	-0.457		
18	0 022	0	0	-0.374	0.058	-0.15		
17	0 057	0	0.007	-0.318	0.084	-0.287		
18	0.014	0	0	-0.28	0.022	-0.077		
	0.8888	AVERAGE VAL		-0.257	0.138	-0.577		



Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STO of Q/D	Relat. STO	meter IO	###### 61651
——	——	——	——	——	——	——	q/d <16	-0.424
1	0	0	0	0	0	0	q/d <50	-0.321
2	3 483	0.666	2.298	-0.16	0.255	-1.588	q/d <84	-0.2
3	10.609	2.909	7.34	-0.131	0.202	-1.544	pk	-0.307
4	16.074	3.776	11.771	-0.141	0.164	-1.165	rsd 7	-0.38
5	12.963	1.926	7.097	-0.177	0.161	-0.906	clc	0.0735
6	12.712	1.293	5.6	-0.216	0.167	-0.76	cws	0.017
7	6.13	0 666	3.16	-0.258	0.171	-0.664	ws 7	0.0056
6	6.399	0.846	2.889	-0.277	0.17	-0.612	d avg(2)	6.76
6	7.281	0.437	1.657	-0.297	0.166	-0.586	corr coe	0
10	5 709	0.325	1.281	-0.309	0.166	-0.536	N	17855
11	4.208	0.146	0.802	-0.329	0.161	-0.461		
12	2.517	0.066	0.417	-0.331	0.154	-0.465		
13	1.556	0.057	0.258	-0.331	0.154	-0.464		
14	0.923	0.032	0.127	-0.33	0.136	-0.421		
15	0.588	0.022	0.077	-0.336	0.146	-0.436		
16	0.34	0.012	0.037	-0.337	0.158	-0.47		
17	0.216	0.007	0.027	-0.338	0.122	-0.38		
16	0.129	0.002	0.007	-0.346	0.136	-0.4		
16	0.07	0.007	0.007	-0.321	0.183	-0.602		
20	0.035	0.005	0.006	-0.302	0.262	-0.668		
21	0.017	0	0	-0.409	0.04	-0.088		
22	0.007	0.002	0.002	-0.146	0.476	-3.213		
23	0.006	0	0	-0.31	0.073	-0.234		
24	0.006	0	0	-0.464	0.045	-0.092		
25	0.002	0	0	-0.652	0	0		
26	0.007	0	0	-0.346	0.102	-0.292		
27	0.002	0	0	-0.653	0	0		
28	0.002	0	0	-0.847	0	0		
	0.9999	AVERAGE VAL		-0.22	0.172	-0.664		



Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STO of Q/D	Relat. STO	meter IO	###### 61650
——	——	——	——	——	——	——	q/d <16	-0.423
1	0	0	0	0	0	0	q/d <50	-0.323
2	6 765	0.745	3.755	-0.202	0.229	-1.133	q/d <84	-0.202
3	19.222	1.303	6.657	-0.195	0.156	-0.801	pk	-0.307
4	20.097	0.716	7.668	-0.229	0.131	-0.57	rsd 7	-0.37
5	12.345	0.17	3.104	-0.27	0.121	-0.448	clc	0.0663
6	11 617	0.147	2.171	-0.295	0.127	-0.433	cws	0.0165
7	8.561	0.098	0.992	-0.322	0.116	-0.37	ws 7	0.0103
6	6.056	0.1	0.88	-0.329	0.114	-0.346	d avg(2)	6.51
6	5.416	0.047	0.383	-0.34	0 109	-0.32	corr coe	0
10	3.644	0.023	0.287	-0.345	0 12	-0.346	N	17044
11	2.048	0.023	0.123	-0.344	0.104	-0.303		
12	1.09	0 006	0.1	-0.346	0.107	-0.308		
13	0.422	0.006	0.047	-0.33	0.117	-0.353		
14	0.284	0.006	0.016	-0.333	0.102	-0.309		
15	0.147	0.006	0.006	-0.355	0.127	-0.358		
16	0.053	0	0.006	-0.346	0.076	-0.227		
17	0.016	0	0	-0.348	0.095	-0.243		
16	0.023	0	0	-0.323	0.073	-0.225		
	0.9999	AVERAGE VAL		-0.284	0.138	-0.554		



Diamet	Relative Freque	% Wron Sign	% Low Charge	Averag Q/D	STO of Q/D	Relat. STO	meter IO	###### 61652
——	——	——	——	——	——	——	q/d <16	-0.425
1	0	0	0	0	0	0	q/d <50	-0.326
2	4 485	0.939	2.766	-0.209	0.305	-1 469	q/d <84	-0.199
3	15.344	2.245	6.831	-0.156	0.167	-1.174	pk	-0.341
4	22.017	1.802	10.552	-0.201	0.146	-0.738	rsd 7	-0.409
5	12 658	0 487	4.165	-0.245	0 135	-0.552	clc	0 1102
6	12.072	0.27	2.831	-0.276	0.134	-0.476	cws	0.034
7	6.442	0.145	1.229	-0.309	0 126	-0.409	ws 7	0.0172
6	6 783	0.076	0.65	-0.329	0.114	-0.346	d avg(2)	6.67
6	5.676	0.135	0.56	-0.333	0.129	-0.386	corr coe	0
10	4.532	0.076	0.311	-0.345	0.117	-0.34	N	16285
11	2 836	0.016	0.145	-0.351	0.112	-0.316		
12	1.333	0	0.088	-0.35	0.098	-0.276		
13	0.638	0.006	0.038	-0.357	0.102	-0.287		
14	0.363	0.006	0.041	-0.343	0.127	-0.371		
15	0.254	0.005	0.021	-0.346	0.116	-0.337		
16	0.093	0	0.016	-0.344	0.162	-0.558		
17	0.052	0	0.006	-0.329	0.098	-0.271		
16	0.021	0	0	-0.421	0.057	-0.136		
19	0.016	0.005	0.005	-0.146	0 429	-2.929		
	1	AVERAGE VAL		-0.253	0.146	-0.859		

APPENDIX E
Taguchi Analysis Charge Spectography

CGSSTD analysis

L9 Orthogonal Array

Factors	Response	Analysis	Signals	Noises	Replicates	Target	SNType
4	CGSstd	Static	0	1	1		nominal-the-best

Levels	3	3	3	3					
Run	MixAuger	ickupAug	xAugerSpe	MOR	Means	StdDev	SNRatios	Betas	AvLoss
1	4890 styl	0.3	400	0.2	-0.228	0.155	3.35		0.08
2	4890 styl	0.5	300	0.25	-0.237	0.183	3.25		0.08
3	4890 styl	0.7	200	0.3	-0.252	0.159	4.00		0.09
4	helical	0.3	300	0.3	-0.227	0.157	3.20		0.08
5	helical	0.5	200	0.2	-0.22	0.172	2.14		0.08
6	helical	0.7	400	0.25	-0.153	0.17	-0.92		0.05
7	4890 styl	0.3	200	0.25	-0.227	0.163	2.68		0.08
8	4890 styl	0.5	400	0.3	-0.177	0.152	1.32		0.05
9	4890 styl	0.7	300	0.2	-0.28	0.153	5.25		0.10

S/N Ratio Factor Effects

	Level1	Level2	Level3	Levl4	Level5	Optimum S/N Ratio	Levels
MixAuger	**3.534449**	1.475086	3.14956			3.53444871	1
PickupAuger	**3.143784**	2.237231	2.77808			3.14378404	1
MixAugerSpeed	1.253169	**3.901024**	3.00491			3.90102365	2
MOR	**3.57976**	1.73761	2.84173			3.57975989	1

Mean Factor Effects

	Level1	Level2	Level3	Level4	Level5	Means
MixAuger	-0.239	-0.2	-0.228			-0.239
PickupAuger	-0.227333	-0.211333	-0.22833			-0.22733333
MixAugerSpeed	-0.186	-0.248	-0.233			-0.248
MOR	-0.242667	-0.205667	-0.21867			-0.24266667

Signal To Noise Ratio

Overall Mean	2.7197
Optimum	5.99992
Total SNRatio SS	90.6071

Response Mean

Overall Mean	-0.22233
Optimum	-0.29
Total Mean SS	0.01136

Beta Factor Effects

	Beta Totial Sum of Squares				
	Level1	Level2	Level3	Level4	Level5
MixAuger					
PickupAuger					
MixAugerSpeed					
MOR					

Loss Factor Effects

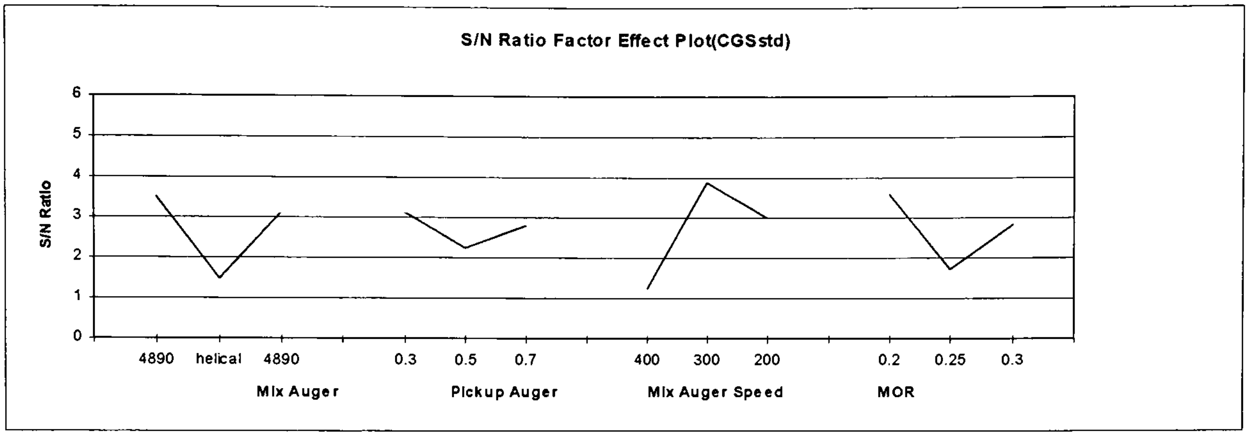
	Level1	Level2	Level3	Level4	Level5
MixAuger	0.082511	0.068824	0.07811		
PickupAuger	0.076762	0.071718	0.08097		
MixAugerSpeed	0.060917	0.086908	0.08162		
MOR	0.085267	0.071048	0.07313		

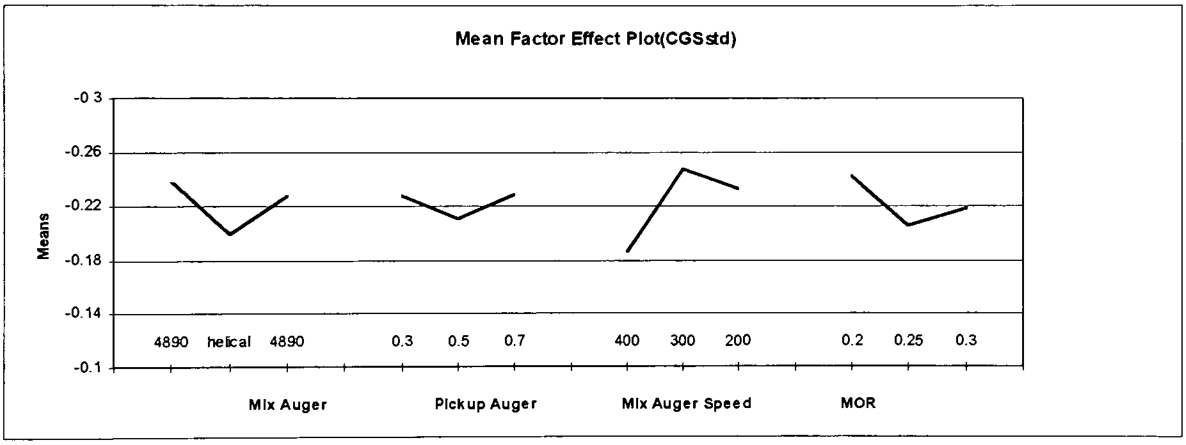
ANOVA Table

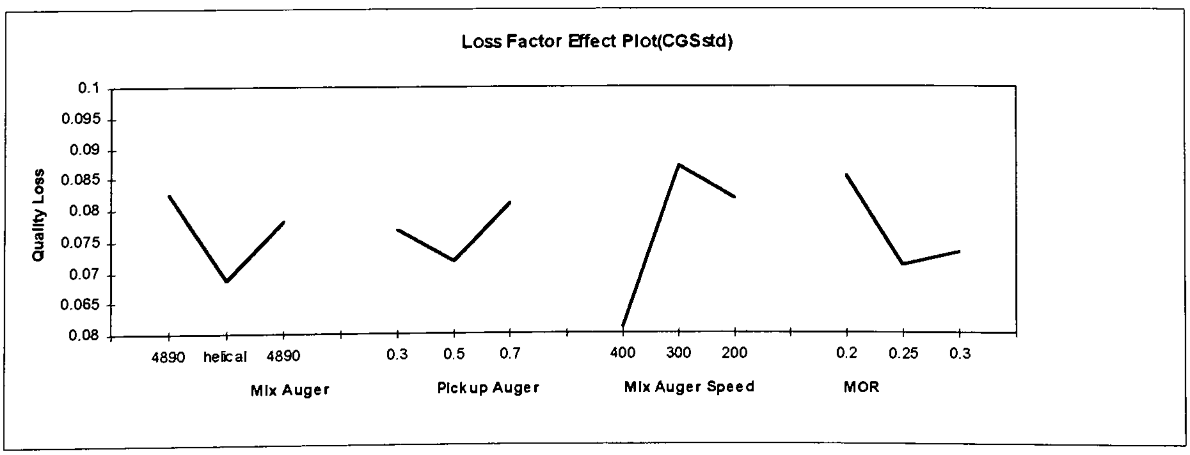
	Correction Factor			0.444889	
Means	DOF	SS	MSV	F Ratio	% Contrib
MixAuger	2	0.002426	0.00121		21.35%
PickupAuger	2	0.000546	0.00027		4.80%
MixAugerSpeed	2	0.006278	0.00314		55.24%
MOR	2	0.002114	0.00106		18.60%
Error	0	5.55E-16			

Factor SS Effects

	Level1	Level2	Level3	Level4	Level5
MixAuger	0.171363	0.12	0.15595		
PickupAuger	0.155041	0.133985	0.15641		
MixAugerSpeed	0.103788	0.184512	0.16287		
MOR	0.176661	0.126896	0.14345		


S/N Ratio Factor Effect Plot(CGSstd)
S/N Ratio
6
5
4
3
2
1
0
4890 helical 4890
0.3 0.5 0.7
400 300 200
0.2 0.25 0.3
Mix Auger
Pickup Auger
Mix Auger Speed
MOR


Mean Factor Effect Plot(CGSstd)
Means
-0 3
-0.26
-0.22
-0.18
-0.14
-0.1
4890 helical 4890
0.3 0.5 0.7
400 300 200
0.2 0.25 0.3
Mix Auger
Pickup Auger
Mix Auger Speed
MOR


Loss Factor Effect Plot(CGSstd)
Quality Loss
0.1
0.095
0.09
0.085
0.08
0.075
0.07
0.065
0.08
4890 helical 4890
0.3 0.5 0.7
400 300 200
0.2 0.25 0.3
Mix Auger
Pickup Auger
Mix Auger Speed
MOR

APPENDIX F
PCA Raw data with Replicates Correlation Matrix

Principal Component Analysis using all the data with replicates

Eigenanalysis of the Correlation Matrix

Eigenvalue	4.7210	0.4778	0.3133	0.1958	0.1812	0.1109
Proportion	0.787	0.080	0.052	0.033	0.030	0.018
Cumulative	0.787	0.866	0.919	0.951	0.982	1.000

Test Point	PC1	PC2	PC3	PC4	PC5	PC6
1	-0.368	0.761	0.493	0.124	-0.107	0.121
2	-0.422	-0.001	-0.556	0.225	-0.084	0.674
3	-0.415	0.252	-0.472	-0.540	-0.125	-0.484
4	-0.425	-0.158	-0.053	0.669	0.317	-0.494
5	-0.415	-0.281	0.317	-0.439	0.636	0.227
6	-0.400	-0.503	0.350	-0.047	-0.679	-0.031

This analysis is performed on the **raw data**. A larger percentage of the variation is explained but the significance has dropped.

Analysis of Variance (Balanced Designs) using L9 with replicates

Factor	Type	Levels	Values
Cell	fixed	9	1 2 3 4 5 6 7 8 9
Noise	fixed	3	0 15 75

Analysis of Variance for Score1

Source	DF	SS	MS	F	P
Cell	8	90.908	11.363	2.91	0.018
Noise	2	26.819	13.409	3.44	0.047
Cell*Noise	16	115.576	7.223	1.85	0.076
Error	27	105.255	3.898		
Total	53	338.557			

Fcritical for cell is:
3.26 at 99% confidence
2.31 at 95% confidence
1.91 at 90% confidence

Fcritical for noise is:
5.49 at 99% confidence
3.35 at 95% confidence
2.51 at 90% confidence

Analysis of Variance for Score2

Source	DF	SS	MS	F	P
Cell	8	6.8066	0.8508	2.12	0.069
Noise	2	0.2994	0.1497	0.37	0.692
Cell*Noise	16	6.5392	0.4087	1.02	0.469
Error	27	10.8426	0.4016		
Total	53	24.4878			

This would mean that at 95% confidence the L9 and the outer array are statistically significant while explaining 78.7% of the variation. PC2 shows L9 to be significant with 90% confidence which explains another 8% of the variation.

Analysis of Variance for Score3

Source	DF	SS	MS	F	P

Cell	8	3.5618	0.4452	1.39	0.244
Noise	2	2.3697	1.1848	3.71	0.038
Cell*Noise	16	3.1283	0.1955	0.61	0.847
Error	27	8.6254	0.3195		
Total	53	17.6852			

Analysis of Variance (Balanced Designs) using L9 with replicates (continue)

Analysis of Variance for Score4

Source	DF	SS	MS	F	P
Cell	8	2.0627	0.2578	1.62	0.165
Noise	2	1.9422	0.9711	6.11	0.006
Cell*Noise	16	1.9819	0.1239	0.78	0.693
Error	27	4.2882	0.1588		
Total	53	10.2749			

Analysis of Variance for Score5

Source	DF	SS	MS	F	P
Cell	8	1.3207	0.1651	0.83	0.585
Noise	2	0.5867	0.2933	1.47	0.247
Cell*Noise	16	2.3515	0.1470	0.74	0.734
Error	27	5.3774	0.1992		
Total	53	9.6362			

APPENDIX G
PCA Raw data with Replicates Covariance Matrix

Principal Component Analysis using all the data with replicates

Eigenanalysis of the **Covariance** Matrix

Eigenvalue	3391.1	352.6	228.7	135.5	129.9	79.1
Proportion	0.786	0.082	0.053	0.031	0.030	0.018
Cumulative	0.786	0.867	0.920	0.952	0.982	1.000

This analysis is performed on the raw data.

Test Point	PC1	PC2	PC3	PC4	PC5	PC6
1	-0.370	0.751	0.507	0.081	0.144	-0.121
2	-0.431	0.012	-0.573	0.179	0.207	-0.641
3	-0.407	0.249	-0.438	-0.583	-0.063	0.487
4	-0.416	-0.135	-0.071	0.728	-0.087	0.516
5	-0.397	-0.243	0.256	-0.154	-0.790	-0.264
6	-0.425	-0.545	0.390	-0.262	0.548	0.031

Analysis of Variance (Balanced Designs) using L9 with replicates

Factor	Type	Levels	Values
Cell	fixed	9	1 2 3 4 5 6 7 8 9
Noise	fixed	3	0 15 75

Analysis of Variance for Score1

Source	DF	SS	MS	F	P
Cell	8	65122	8140	2.90	0.018
Noise	2	19425	9712	3.46	0.046
Cell*Noise	16	83019	5189	1.85	0.077
Error	27	75763	2806		
Total	53	243329			

Again the L9 and outer array are significant at 95% confidence regardless of the change from correlation matrix to the covariance matrix.

Analysis of Variance for Score2

Source	DF	SS	MS	F	P
Cell	8	5018.6	627.3	2.12	0.069
Noise	2	172.3	86.1	0.29	0.749
Cell*Noise	16	4686.7	292.9	0.99	0.493
Error	27	7979.1	295.5		
Total	53	17856.6			

Analysis of Variance for Score3

Source	DF	SS	MS	F	P
Cell	8	2540.8	317.6	1.35	0.264
Noise	2	1903.5	951.7	4.03	0.029

Cell*Noise	16	2256.2	141.0	0.60	0.858
Error	27	6374.6	236.1		
Total	53	13075.1			

Analysis of Variance for Score4

Source	DF	SS	MS	F	P
Cell	8	1649.3	206.2	1.96	0.092
Noise	2	1539.4	769.7	7.31	0.003
Cell*Noise	16	1457.6	91.1	0.86	0.611
Error	27	2844.7	105.4		
Total	53	7491.0			

Analysis of Variance for Score5

Source	DF	SS	MS	F	P
Cell	8	825.3	103.2	0.70	0.692
Noise	2	99.3	49.6	0.33	0.718
Cell*Noise	16	1676.0	104.8	0.71	0.763
Error	27	4000.8	148.2		
Total	53	6601.4			

APPENDIX H
PCA Raw data with Means Correlation Matrix

Principal Component Analysis using all the data with means

Eigenanalysis of the **Correlation** Matrix

Eigenvalue	4.6773	0.5370	0.3001	0.2287	0.1373	0.1197
Proportion	0.780	0.089	0.050	0.038	0.023	0.020
Cumulative	0.780	0.869	0.919	0.957	0.980	1.000

Test Point	PC1	PC2	PC3	PC4	PC5	PC6
1	-0.379	-0.596	0.595	-0.365	0.091	-0.083
2	-0.427	-0.113	-0.413	0.205	0.677	-0.366
3	-0.414	-0.380	-0.193	0.540	-0.341	0.490
4	-0.415	0.088	-0.505	-0.618	-0.417	-0.091
5	-0.410	0.421	0.361	0.357	-0.357	-0.519
6	-0.403	0.551	0.230	-0.155	0.340	0.584

This analysis is performed on the **raw data** while averaging the replicates.

Analysis of Variance (Balanced Designs) using L9 with means

Factor	Type	Levels	Values
cell	fixed	9	1 2 3 4 5 6 7 8 9
noise	fixed	3	0 15 75

Analysis of Variance for score1

Source	DF	SS	MS	F	P
cell	8	73.218	9.152	1.97	0.118
noise	2	21.637	10.818	2.33	0.129
Error	16	74.294	4.643		
Total	26	169.148			

Analysis of Variance for score2

Source	DF	SS	MS	F	P
cell	8	5.9414	0.7427	2.67	0.045
noise	2	0.2138	0.1069	0.38	0.687
Error	16	4.4476	0.2780		
Total	26	10.6028			

Analysis of Variance for score3

Source	DF	SS	MS	F	P
cell	8	1.9380	0.2423	1.02	0.457
noise	2	2.5610	1.2805	5.42	0.016
Error	16	3.7832	0.2364		
Total	26	8.2823			

There is not enough degrees of freedom to determine the significance of the interaction between the L9 and the outer array when the replicates are averaged.

Fcritical for cell:
3.89 at 99% confidence
2.59 at 95% confidence
2.09 at 90% confidence

F critical for noise:
6.23 at 99% confidence
3.63 at 95% confidence
2.67 at 90% confidence

Analysis of Variance (Balanced Designs) using L9 with means

Analysis of Variance for score4

Source	DF	SS	MS	F	P
cell	8	2.4473	0.3059	1.74	0.164
noise	2	0.5591	0.2795	1.59	0.234
Error	16	2.8083	0.1755		
Total	26	5.8147			

Analysis of Variance for score5

Source	DF	SS	MS	F	P
cell	8	1.5240	0.1905	1.34	0.293
noise	2	0.0378	0.0189	0.13	0.876
Error	16	2.2708	0.1419		
Total	26	3.8326			

APPENDIX I
PCA Raw data with Means Correlation Matrix

Principal Component Analysis using all the data with means

Eigenanalysis of the Covariance Matrix

Eigenvalue	2293.1	260.4	131.2	108.0	69.1	61.1	
Proportion	0.785	0.089	0.045	0.037	0.024	0.021	Raw data
Cumulative	0.785	0.874	0.919	0.955	0.979	1.000	

Test Point	PC1	PC2	PC3	PC4	PC5	PC6
1	-0.327	-0.436	0.624	-0.539	0.136	-0.066
2	-0.436	-0.175	-0.387	0.171	0.749	-0.196
3	-0.448	-0.493	-0.012	0.510	-0.404	0.366
4	-0.404	0.054	-0.569	-0.547	-0.432	-0.156
5	-0.390	0.383	0.332	0.337	-0.214	-0.657
6	-0.432	0.622	0.163	-0.086	0.157	0.606

Analysis of Variance (Balanced Designs) using L9 with means

Factor	Type	Levels	Values
cell	fixed	9	1 2 3 4 5 6 7 8 9
noise	fixed	3	0 15 75

Analysis of Variance for score1

Source	DF	SS	MS	F	P
cell	8	35488	4436	1.93	0.126
noise	2	10201	5101	2.22	0.141
Error	16	36838	2302		
Total	26	82527			

Analysis of Variance for score2

Source	DF	SS	MS	F	P
cell	8	2980.8	372.6	3.51	0.016
noise	2	142.8	71.4	0.67	0.524
Error	16	1696.7	106.0		
Total	26	4820.3			

Analysis of Variance for score3

Source	DF	SS	MS	F	P
cell	8	948.9	118.6	1.07	0.427
noise	2	1103.1	551.6	4.99	0.021
Error	16	1767.6	110.5		
Total	26	3819.7			

Analysis of Variance for score4

Source	DF	SS	MS	F	P
cell	8	1044.14	130.52	1.60	0.202
noise	2	310.02	155.01	1.90	0.182
Error	16	1305.80	81.61		
Total	26	2659.96			

Analysis of Variance for score5

Source	DF	SS	MS	F	P
cell	8	749.22	93.65	1.32	0.300
noise	2	43.00	21.50	0.30	0.742
Error	16	1132.14	70.76		
Total	26	1924.37			

APPENDIX J
PCA Normalized data with Replicates Correlation Matrix

Principal Component Analysis using all the data with replicates

This analysis is done on the data normalized by D Joe Voelkel

Eigenanalysis of the **Correlation** Matrix

Eigenvalue	1.9298	1.4475	1.1132	0.8699	0.6396	0.0000
Proportion	0.322	0.241	0.186	0.145	0.107	0.000
Cumulative	0.322	0.563	0.748	0.893	1.000	1.000

Test Point	PC1	PC2	PC3	PC4	PC5	PC6
1	0.353	0.600	-0.407	-0.164	-0.218	0.525
2	0.282	-0.646	0.099	-0.040	-0.600	0.363
3	0.516	-0.062	0.452	0.167	0.598	0.374
4	-0.235	-0.402	-0.676	0.242	0.396	0.333
5	-0.441	0.239	0.297	0.684	-0.239	0.367
6	-0.529	-0.025	0.275	-0.646	0.142	0.455

Analysis of Variance (Balanced Designs) for the L9 cells with replicates

Factor	Type	Levels	Values
Cell	fixed	9	1 2 3 4 5 6 7 8 9
Noise	fixed	3	0 15 75

Analysis of Variance for Score1

Source	DF	SS	MS	F	P
Cell	8	40.9350	5.1169	6.10	0.000
Noise	2	0.8406	0.4203	0.50	0.611
Cell*Noise	16	20.2364	1.2648	1.51	0.168
Error	27	22.6417	0.8386		
Total	53	84.6537			

Analysis of Variance for Score2

Source	DF	SS	MS	F	P
Cell	8	9.128	1.141	0.70	0.685
Noise	2	15.317	7.658	4.73	0.017
Cell*Noise	16	22.128	1.383	0.85	0.622
Error	27	43.739	1.620		
Total	53	90.312			

Analysis of Variance for Score3

Source	DF	SS	MS	F	P
Cell	8	10.8438	1.3555	1.45	0.223

Noise	2	7.8326	3.9163	4.18	0.026
Cell*Noise	16	15.0911	0.9432	1.01	0.479
Error	27	25.2891	0.9366		
Total	53	59.0567			

Analysis of Variance (Balanced Designs) for the L9 cells with replicates (continue)

Analysis of Variance for Score4

Source	DF	SS	MS	F	P
Cell	8	6.333	0.792	0.78	0.621
Noise	2	2.538	1.269	1.26	0.301
Cell*Noise	16	10.313	0.645	0.64	0.825
Error	27	27.268	1.010		
Total	53	46.451			

Analysis of Variance for Score5

Source	DF	SS	MS	F	P
Cell	8	6.9647	0.8706	1.22	0.326
Noise	2	1.2122	0.6061	0.85	0.439
Cell*Noise	16	9.6790	0.6049	0.85	0.629
Error	27	19.2992	0.7148		
Total	53	37 1551			

APPENDIX K
PCA Normalized data with Replicates Covariance Matrix

Principal Component Analysis using all the data with replicates

Eigenanalysis of the **Covariance** Matrix

Eigenvalue	356.76	231.37	135.64	130.73	79.18	0.00
Proportion	0.382	0.248	0.145	0.140	0.085	0.000
Cumulative	0.382	0.630	0.775	0.915	1.000	1.000

This analysis is performed c the normalized data.

Test Point	PC1	PC2	PC3	PC4	PC5	PC6
1	0.748	0.473	-0.096	0.159	-0.124	-0.408
2	-0.022	-0.590	-0.189	0.197	-0.640	-0.408
3	0.225	-0.451	0.585	-0.032	0.486	-0.408
4	-0.153	-0.081	-0.723	-0.123	0.516	-0.408
5	-0.244	0.263	0.193	-0.772	-0.268	-0.408
6	-0.554	0.386	0.230	0.569	0.031	-0.408

Analysis of Variance (Balanced Designs) using L9 with replicates

Factor	Type	Levels	Values
Cell	fixed	9	1 2 3 4 5 6 7 8 9
Noise	fixed	3	0 15 75

Analysis of Variance for Score1

Source	DF	SS	MS	F	P
Cell	8	4874.1	609.3	2.13	0.068
Noise	2	72.4	36.2	0.13	0.881
Cell*Noise	16	5371.3	335.7	1.18	0.345
Error	27	7712.0	285.6		
Total	53	18029.9			

Analysis of Variance for Score2

Source	DF	SS	MS	F	P
Cell	8	2844.6	355.6	1.66	0.155
Noise	2	1703.1	851.5	3.97	0.031
Cell*Noise	16	2465.7	154.1	0.72	0.752
Error	27	5789.7	214.4		
Total	53	12803.0			

Analysis of Variance for Score3

Source	DF	SS	MS	F	P
Cell	8	1615.2	201.9	1.86	0.109
Noise	2	1488.5	744.3	6.85	0.004

Cell*Noise	16	1417.3	88.6	0.82	0.659
Error	27	2932.6	108.6		
Total	53	7453.6			

Analysis of Variance for Score4

Source	DF	SS	MS	F	P
Cell	8	861.2	107.7	0.72	0.673
Noise	2	177.7	88.9	0.59	0.560
Cell*Noise	16	1656.5	103.5	0.69	0.778
Error	27	4044.3	149.8		
Total	53	6739.7			

Analysis of Variance for Score5

Source	DF	SS	MS	F	P
Cell	8	869.07	108.63	1.37	0.253
Noise	2	235.08	117.54	1.48	0.244
Cell*Noise	16	1384.56	86.53	1.09	0.407
Error	27	2137.27	79.16		
Total	53	4625.98			

APPENDIX L
PCA Normalized data with Replicates Correlation Matrix

Principal Component Analysis using all the data with means

Eigenanalysis of the Covariance Matrix

Eigenvalue	239.87	143.80	78.65	63.83	40.76	0.00
Proportion	0.423	0.254	0.139	0.113	0.072	0.000
Cumulative	0.423	0.677	0.815	0.928	1.000	1.000

Test Point	PC1	PC2	PC3	PC4	PC5	PC6
1	0.571	-0.647	-0.270	-0.028	0.126	-0.408
2	0.184	0.539	0.002	0.244	0.670	-0.408
3	0.320	0.212	0.468	0.296	-0.616	-0.408
4	-0.074	0.366	-0.498	-0.594	-0.306	-0.408
5	-0.373	-0.260	0.605	-0.457	0.227	-0.408
6	-0.627	-0.211	-0.307	0.539	-0.102	-0.408

This analysis was performed using the normalized averages.

Analysis of Variance (Balanced Designs) using the L9 with means

Factor	Type	Levels	Values
Cell	fixed	9	1 2 3 4 5 6 7 8 9
Noise	fixed	3	0 15 75

Analysis of Variance for score1

Source	DF	SS	MS	F	P
Cell	8	2832.8	354.1	2.63	0.048
Noise	2	89.2	44.6	0.33	0.723
Error	16	2155.2	134.7		
Total	26	5077 1			

Analysis of Variance for score2

Source	DF	SS	MS	F	P
Cell	8	810.0	101.2	0.95	0.508
Noise	2	1224.3	612.2	5.72	0.013
Error	16	1713.6	107.1		
Total	26	3747.9			

Analysis of Variance for score3

Source	DF	SS	MS	F	P
Cell	8	692.46	86.56	2.18	0.088
Noise	2	194.73	97.36	2.45	0.118
Error	16	635.58	39.72		
Total	26	1522.77			

Analysis of Variance for score4

Source	DF	SS	MS	F	P
Cell	8	739.91	92.49	1.41	0.266
Noise	2	269.35	134.67	2.05	0.161
Error	16	1050.12	65.63		
Total	26	2059.38			

Analysis of Variance for score5

Source	DF	SS	MS	F	P
Cell	8	457.07	57.13	1.54	0.219
Noise	2	60.89	30.44	0.82	0.458
Error	16	593.19	37.07		
Total	26	1111.15			

APPENDIX M
PCA Normalized data with Replicates Covariance Matrix

Principal Component Analysis using all the data with means

Eigenanalysis of the **Correlation** Matrix

Eigenvalue	2.2987	1.5020	0.9640	0.6908	0.5445	0.0000
Proportion	0.383	0.250	0.161	0.115	0.091	0.000
Cumulative	0.383	0.633	0.794	0.909	1.000	1.000

Variable	PC1	PC2	PC3	PC4	PC5	PC6
DATA 1	-0.295	0.582	0.527	0.091	0.182	0.505
DATA 2	-0.389	-0.462	-0.299	0.341	0.550	0.357
DATA 3	-0.481	0.109	-0.480	-0.237	-0.590	0.350
DATA 4	0.026	-0.629	0.518	-0.431	-0.183	0.342
DATA 5	0.481	0.194	-0.362	-0.543	0.389	0.393
DATA 6	0.546	-0.060	-0.057	0.582	-0.363	0.474

This analysis is performed on the average of the replicates of the **normalized data**. What we can conclude is the use of normalized data increases your significance but reduces the percent of variation which is explained by the analysis.

Analysis of Variance (Balanced Designs) using the L9 with means

Factor	Type	Levels	Values
Cell	fixed	9	1 2 3 4 5 6 7 8 9
Noise	fixed	3	0 15 75

Analysis of Variance for SCORE1

Source	DF	SS	MS	F	P
Cell	8	30.5680	3.8210	4.13	0.008
Noise	2	3.2054	1.6027	1.73	0.209
Error	16	14.8172	0.9261		
Total	26	48.5906			

Analysis of Variance for SCORE2

Source	DF	SS	MS	F	P
Cell	8	9.820	1.227	1.07	0.431
Noise	2	14.279	7 139	6.21	0.010
Error	16	18.399	1.150		
Total	26	42.498			

Analysis of Variance for SCORE3

Source	DF	SS	MS	F	P
Cell	8	9.8491	1.2311	1.48	0.240
Noise	2	1.9835	0.9918	1.19	0.329
Error	16	13.3090	0.8318		
Total	26	25.1416			

Analysis of Variance for SCORE4

Source	DF	SS	MS	F	P
Cell	8	6.5784	0.8223	1.22	0.350
Noise	2	1.4195	0.7097	1.05	0.373
Error	16	10.8204	0.6763		
Total	26	18.8183			

Analysis of Variance for SCORE5

Source	DF	SS	MS	F	P
Cell	8	5.1589	0.6449	1.60	0.201
Noise	2	1.1225	0.5613	1.40	0.276
Error	16	6.4357	0.4022		
Total	26	12.7171			